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STUDY OF METEOROLOGICAL CONDITIONS ALONG ACTUAL OR PROPOSED REENTRY TRAJECTORIES

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Final Report
December 1978 - March 1981

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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The Air Force Geophysics Laboratory (AFGL) has been tasked by the Space Division (SD) of the Air Force Systems Command to provide meteorological support and analyses in support of the Advanced Ballistic Reentry Systems (ABRES) Program. The primary objectives of the work carried out under this contract by Environmental Research & Technology, Inc. (ERT) have been to assist AFGL in (1) the design and analyses of experiments to assess the probable error of the AFGL aircraft/radar methodology for characterizing the cloud microphysical environment along a reentry trajectory, (2) the development and testing of improved analytical

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20. ABSTRACT (cont)

methods for describing the cloud microphysical environment along a reentry trajectory, and (3) the generation of environmental statistics to be used as input to operations analyses of possible future reentry tests of experiments. Another major portion of the work involved the maintenance and running of many computer programs; these programs have been documented and form a part of this report.

The major results accomplished or obtained include: (1) the description and documentation of ten computer programs used for the processing and analysis of aircraft and weather radar data, (2) the overall RMS uncertainties associated with the radar measurements of radar reflectivity from cloud and precipitation at Kwajalein are estimated to be 1.0 dB for both the ALCOR and TRADEX, (3) using the multi-frequency radars at Kwajalein, 80 μm ice particles with densities as low as 42 m^{-3} could be detected at a range of 42 km, and (4) an assessment of the airborne AN/APQ-122(V) 8 radar led to a series of recommendations regarding its suitability for estimating the liquid water content ahead of the aircraft.

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1. INTRODUCTION

The Air Force Geophysics Laboratory (AFGL) has been tasked by the Space Division (SD) of the Air Force Systems Command to provide meteorological support and analyses in support of the Advanced Ballistic Reentry Systems (ABRES) Program. The primary objectives of the work carried out under this contract by Environmental Research & Technology, Inc. (ERT) have been to assist AFGL in (1) the design and analyses of experiments to assess the probable error of the AFGL aircraft/radar methodology for characterizing the cloud microphysical environment along a reentry trajectory, (2) the development and testing of improved analytical methods for describing the cloud microphysical environment along a reentry trajectory, and (3) the generation of environmental statistics to be used as input to operations analyses of possible future reentry tests of experiments. Another major portion of the work involved the maintenance and running of many computer programs; these programs have been documented and form a part of this report.

Throughout the two-year period of the contract, the work was broken down into six tasks. The task titles are:

1) Cloud and Precipitation Descriptions for Ten Case Studies,
2) Assessment of Radar Parameters for Hydrometeor Scatter Measurement Using the ALCOR and TRADEX Radars at Kwajalein,
3) The Weather Correlation Runs of June 26, 1979 at Kwajalein,
4) Cirrus Cloud Particle Detectability Using the Kwajalein Radars,
5) Assessment of Airborne Radar AN/APQ-122(V) 8 for Use in Quantitative Measurements of Liquid Water Content, and
6) The Processing of Radar and Aircraft Weather Data from Wallops Island.

This report describes the key results of each of the six tasks. In addition, the procedure for assigning the liquid water content in various atmospheric layers is presented in Appendix D.

2. ANALYSES AND SUPPORT

2.1 Task 1 - The Processing of Radar and Aircraft Weather Data from Wallops Island

An important part of this program was the maintenance and running of many different types of computer programs. The programs were designed to process weather radar and aircraft data of clouds and precipitation. There were 10 major programs which were run at various intervals over the two-year span of the program, and a total of more than 500 computer runs were made.

Documentation of the computer programs used throughout the program is given in Appendix A. A listing of all of the computer programs is available from the Meteorology Division of the Air Force Geophysics Laboratory.

2.2 Task 2 - Assessment of Radar Parameters for Hydrometeor Scatter Measurements Using the ALCOR and TRADEX Radars at Kwajalein

The results of this task have been described in a report by Blood and Crane (1979). The report documents the scattering relationships and radar parameters which enter into the measurement of effective radar reflectivity, Z_e, obtained from the ALCOR (C-band) and TRADEX (S-band) radars operated at Kwajalein Atoll for hydrometeor scatter investigations. An assessment is given of the calibration procedures used for the radars including assumptions, corrections, and uncertainties associated with the parameters used in the measurements. The current best estimate radar constants for ice and water used for data processing are documented for users of the data together with an editing criteria for rain data based upon the principal-to-opposite polarization received power ratios.

The summary and conclusions of the report are as follows:

> "The ALCOR (C-band) and TRADEX (S-band) radars at Kwajalein are well-calibrated instrumentation radars which serve among many other roles to provide measurements of the environmental conditions of hydrometeor activity within the reentry corridor of the Kwajalein Missile Range (KMR). The report defines the essential radar parameters, assesses significant

sources of errors in these parameters and documents the most recent best estimate of the appropriate radar constants to use in data processing. A discussion of the calibration procedures is also given with a recognition of the ultimate importance of sphere calibrations in close space and time proximity to the hydrometeor scatter measurements of interest for minimizing the calibration uncertainties. The overall RMS (1σ) uncertainties associated with the radar measurement are estimated at 1.0 dB each for ALCOR and TRADEX. This assumes that the bias terms associated with signal processing are appropriately accounted for by the use of the best estimate correction factor and that the radar parameters do not change. Implicit in this analysis is the assumption that a zero dB polarization mis-match loss occurs for hydrometeor scatter and that excess losses, such as radome attenuation changes due to rain or condensation of moisture on the ALCOR radome, do not occur during the measurements.

An initial attempt to classify rain scatter on the basis of principal-to-opposite polarization ratio is presented. This tool, useful for data editing and interpretation, suggests that further means of classifying the hydrometeor backscatter may be intrinsically available in the different radar polarizations and worthwhile for further investigation at Kwajalein."

2.3 Task 3 - The Weather Correlation Runs of June 26, 1979 at Kwajalein

The purpose of the linked-radar/aircraft experiment on June 26, 1979 at Kwajalein was to collect data simultaneously by radar backscatter and by on-board aircraft measurements of the hydrometeor type and size distribution for correlation and calibration purposes. The details, results, and recommendations of the experiment are provided in Appendix B.

2.4 Task 4 - Cirrus Cloud Particle Detectability Using the Kwajalein Radars

The ability to make measurements of low particle densities of tenuous clouds by radar is of interest to the question of reentry vehicle surface erosion. A report on the detection of low concentration particles within cirrus clouds is given in Appendix C. The conclusion of the study is that, using the multi-frequency radars at Kwajalein, 80 μm ice particles with densities as low as 42 m^{-3} could be detected at a range of 42 km using the TRADEX L-band chirp system.

2.5 Task 5 - Assessment of Airborne Radar AN/APQ-122 (V) 8 for Use in Quantitative Measurements of Liquid Water Content

2.5.1 Introduction

This report summarizes the findings of an investigation into the potential scientific use of a multi-function airborne radar to be referred to as the APQ-122, which is currently operating on-board an instrumented C-130 aircraft. The radar is being considered for use in quantitative measurements of liquid water content in addition to its currently designed modes of weather mapping and other functions. In order to perform these data collection measurements, an investigation was initiated toward possibly using the radar outputs for making reflectivity measurements in a pulse volume just ahead of the aircraft. The purpose was to define the probable use of the instrument without major modification of existing hardware and to define auxiliary sampling and recording equipment that would be needed for collecting the desired measurements.

An initial look at the sensitivity of the radar at Ka- and X-bands (Blood, 1980) seemed to indicate that the desired levels of liquid water content would be detectable providing that the radar output could be sampled at ranges of nominally 1-2 Kft ahead of the aircraft. Mr. Vernon G. Plank (private communication) indicated that detectable thresholds of 0.003 g/m^3 at Ka-band and 0.001 g/m^3 at X-band (long pulse) should be adequate for measuring cirrus type particles.

Further information, however, was needed to assess the performance to be expected from the instrument. Due to the lack of immediate access to equipment manuals, specifications and any available specific measurements of the type needed to completely describe the APQ-122 radar performance at near range, ERT requested that additional information be obtained through the Radar Branch at Wright Patterson AFB. The AF responses and flight manual specifications have been used to help specify additional tests that may be needed and to propose a tentative plan of radar instrument usage, should all of the assumptions be verified. It currently looks promising for the quantitative data to be collected; however, several unknowns about performance remain. The questions that need further verification are: (1) are the Ka-band and X-band

transmitter/receiver systems stable? (2) does the radar have adequate sensitivity and dynamic range at the near ranges (clutter free)? and (3) can the signal amplitude be calibrated with minimal bias errors and uncertainties (~1 to 2 dB each)?

With the APQ-122 operating in the weather mode (pencil beam) and the antenna in a stop mode oriented ahead of the aircraft and compensated for aircraft drift angle on a horizontal flight path, current findings are that the radar should be able to sense the reflectivity levels (amplitude only) at ranges between 270 m (900 ft) and 750 m (2500 ft). The APQ-122 contains two completely separate transmitter/receiver units. As described in the operator's flight manual LTM1MC-130E-1, both the Ka-band (~33 GHZ) and X-band (~9.36 GHz) radar frequencies may not be operated simultaneously as the mapping antenna is shared in the weather mode; thus the X-band mapping functions are not available during Ka-band mapping; i.e., the Ka-band mapping subsystem, when operating, has priority over the X-band system, and X-band automatically reverts to standby. The pencil beam mode is selectable (versus fan beam), and the antenna servos receive positioning information from the electronic control amplifier in the form of tilt, roll, pitch, drift, and azimuth drive commands which compensate for airplane maneuvers. The tilt (vertical) angle is selectable from 10° upward to 15° downward from horizontal with the aircraft.

The exact use of the two (Ka- and X-) radar bands has not been completely determined, and usage may depend on the type of particles being sampled. It may be desirable to use either radar depending on the altitude being studied. The 33 GHz frequency may be better for ice measurements at higher altitude and the 9 GHz frequency more optimum for rain at lower altitudes. At Ka-band the reflectivity of ice is higher than at X-band; however, when within rain, Ka frequency is not as desirable as X-band due to increased wave propagation attenuation. The option of using either system may be desirable pending experimental observations at which time an operational procedure may be established.

The following sections describe the radar sensitivities expected, preparatory test recommendations (validation), and a tentative outline of data collection requirements. Attempts have been made to indicate the assumptions where quantitative measurements are not yet available.

In order to guarantee a successful experiment, prior to the fabrication of the hardware each uncertainty should be checked either by bench measurement, within the aircraft, or against such manufacturers tests which may already exist on the specific unit to be flown.

2.5.2 System Sensitivity to Detect Ice and Water

The Ka-band radar (0.2 μs pulse width) sensitivity was estimated by Blood (1980); it was based on quoted nominal values of transmitted power, antenna beamwidths and receiver sensitivity at pulse repetition frequencies (PRFs) of 2000 and 4000 PPS. An integration gain of 17 dB (0.589 sec) was obtained at 4000 PPS whereby 2560 pulses would be averaged incoherently during the time that 2.63 resolution volumes would be swept out by the aircraft at a 260 Knot indicated air speed (IAS). The resulting level of dBZe detectable for ice at a range of 1000 meters was -18 dBZe at a 10 dB S/N level. For water, a 6 dB lower dBZe level was obtained under the same conditions. If the lower (2000 PPS) PRF were to be used, the processing gain proportional to $\sqrt{N}$ would drop to 15.5 dB, and detectable levels would be reduced by 1.5 dB. In considering the system losses to arrive at these values, a nominal 5 dB value was estimated (Blood, 1980). This loss, typical for airborne weather radar, usually breaks down as follows: radome, 1.5 dB; waveguide and mismatch losses, 1.0 dB; antenna losses, 1 dB; and beam shape loss, 1.5 dB. The actual system losses of the APQ-122, however, are currently unknown. Quoted values were used for other parameters including a receiver minimum discernable signal (MDS) of -90 dBM. Not considered in the receiver sensitivity however was the existence of a built-in (fixed) STC, sensitivity-time control taper. The STC depth was assumed to be manually controllable in the weather mode and therefore settable to zero. Since the STC values were completely unspecified, nothing can be definitely stated about the K-band radar's capability in achieving the above reflectivities based on the -90 dBM MDS value. Further, since no actual system losses were given, the departures from the estimated 5 dB value may be several dB.

At X-band, the detectability was based on the most sensitivity (long pulse) waveform of 4 μs duration. In view of the probable receiver recovery estimate of at least 4 pulse widths (i.e., 16 μs = 2400 m),

this was perhaps an unrealistic waveform choice for X-band. The narrower pulse width (0.6 and 0.3 μs) X-band waveforms have therefore been reexamined in Table 1 along with those previously reported at Ka-band. Choosing the higher PRF (narrowest pulse) waveform, the integration gain for 4096 pulses is about 18 dB. During this integration time, 6.1 resolution volumes are swept out. With an 18 dB processing gain, a revised X-band sensitivity estimate is given in Table 2 (lower portion) for the 0.3 s pulse. The X-band radar is less sensitive with this waveform than at 4 μs (MDS = -98 versus -106 dBM) and consequently, because of the lower sensitivity and scattering volume size, the level of reflectivity is reduced considerably (-10 dBZe versus -25 dBZe for ice at 4 μs and 1000 M).

In all probability, the receiver outputs at Ka- and X-bands, as mentioned previously, may be sampled at ranges between 270 m and 750 m. Using the 750-meter value as a conservative estimate, the detectability at Ka-band for ice would be -20.5 dBZe (∿.003 g/m^3 LWC) and at X-band, -12.5 dBZe (∿.008 g/m^3 LWC). A more exact definition of the radar detectability may be made once the near-range receiver response characteristic has been determined from measurement. It is necessary that all feed-through modulation and near-range "clutter" type returns have decayed to the receiver noise level quoted or the sensitivities will be degraded correspondingly. The radar parameters used in these detectability estimates are given in Table 3 including the size of the illuminated volume assuming a filled beam and single pulse width resolution at a range of 750 meters ahead of the aircraft. Blood (1980) describes all of the relationships used.

2.5.3 Preparatory Test Recommendations

<u>Transmitter/Receiver Stability</u>

Liquid water content measurements are derived from effective radar reflectivity measurements (dBZe) which in turn are derived from calibrated amplitude measurements of the received power from a gated portion of the receiver output. These measurements therefore depend on amplitude stability of the transmitter-receiver system both pulse-to-pulse and over a long period of time. It is probable that magnetron power outputs

TABLE 1

PARAMETERS IN RADAR SIGNAL PROCESSING FOR AIRBORNE HYDROMETEOR SCATTER MEASUREMENTS

PARAMETER	@ Ka-Band (λ=0.0092 m)		@ X-Band (λ=0.032 m)		
PRF	2000 PPS	4000 PPS	250 PPS	1000 PPS	2000 PPS
pulse width τ:	0.2 μs	0.2 μs	4 μs	0.6 μs	0.3 μs
$\Delta R = c\tau/2$:	30 m	30 m	600 m	90 m	45 m
T = PRI:	0.5 ms	0.25 ms	4 ms	1 ms	0.5 ms
Ra = folding range:	75 km	37.5 km	600 km	150 km	75 km
$\Delta\tau_c$ = decorrelation:	4.6 ms	4.6 ms	16 ms	16 ms	16 ms
N_c = pulses/decorr.	~10	~20	4	16	32
N_I = indep. samp.: (σ_z(dB)~.5 dB)	128	128	128	128	128
$\Delta\tau$ = integ. time:	0.589 sec	0.589 sec	2.048 sec	2.048 sec	2.048 sec
No. vols swept:	2.63 vols	2.63 vols	0.457 vols	3.04 vols	6.09 vols
S = sweep out rate @ 260 Kts	0.224 sec/vol	0.224 sec/vol	4.48 sec/vol	0.673 sec/vol	0.336 sec/vol
N = No. pulses:	1280	2560	512	2048	4096
N_{min} = Min No. Pulses:	448	896	512 (same)	672	672
Integ. Gain @ N:	15.5 dB	17.0 dB	13.5 dB	16.6 dB	18.1 dB
Integ. Gain @ N_{min}:	13.3 dB	14.8 dB	13.5 dB	14.1 dB	14.1 dB

TABLE 2

RADAR SENSITIVITIES IN DETECTING ICE REFLECTIVITY
(note: water = [ ])

Ka-Band, 0.2 μs, 4000 PPS

PARAMETER	RANGE (M) 250	500	750*	1000	2500
1) single pulse MDS (dBZe) (no losses)	-25.5 (dBZe) [-31.5]	-19.5 (dBZe) [-25.5]	-16 (dBZe) [-22.0]	-13.5 (dBZe) [-19.5]	-5.5 (dBZe) [-11.5]
2) integration gain @ 4000 PPS	17 dB	17 dB	17 dB	17 dB	17 dB
3) est. system losses	5 dB	5 dB	5 dB	5 dB	5 dB
4) avg. of log amplitudes	2.5 dB	2.5 dB	2.5 dB	2.5 dB	2.5 dB
5) required S/N (assumed)	10 dB	10 dB	10 dB	10 dB	10 dB
Level of Detectable dBZe @ 10 dB S/N: 1)-2)+3)-4)+5)	-30 dBZe [-36 dBZe]	-24 dBZe [-30]	-20.5 dBZe [-26]	-18 dBZe [-24]	-10 dBZe [-16]

X-Band, 0.3 μs, 2000 PPS

PARAMETER	RANGE (M) 250	500	750*	1000	2500
1) single pulse MDS (dBZe) (no losses)	-16.5 (dBZe) [-23]	-10.5 (dBZe) [-17]	-7.0 (dBZe) [-13.5]	-4.5 (dBZe) [-11]	+3.5 (dBZe) [-3]
2) integration gain @ 2000 PPS PPS (Table 1, normal case)	~18 dB	~18 dB	~18 dB	~18 dB	~18 dB
3) est. system losses*	5 dB	5 dB	5 dB	5 dB	5 dB
4) avg. of log amplitudes	2.5 dB	2.5 dB	2.5 dB	2.5 dB	2.5 dB
5) required S/N (assumed)	10 dB	10 dB	10 dB	10 dB	10 dB
Level of Detectable dBZe @ 10 dB S/N: 1)-2)+3)-4)+5)	-22 dBze [-28.5 dBZe]	-16 dBZe [-22.5]	-12.5 dBZe [-19]	-10 dBZe [-16.5]	-2 dBZe [-8.5]

*most probable gating range

TABLE 3

RADAR PARAMETERS* USED IN SENSITIVITY ESTIMATE FOR LIQUID WATER CONTENT MEASUREMENT

PARAMETER	Ka-BAND	X-BAND
frequency	32.2 to 33.0 GHz	9.1 to 9.5 GHz
λ (nominal)	0.92×10^{-2} m	3.2×10^{-2} m
P_t (peak)	6×10^4 watts	6×10^4 watts
G (pencil beam)	1.585×10^4 (42 dBI)	1.585×10^3 (32 dBI)
Beamwidths { θ (azimuthal, 3 dB)	1.38×10^{-2} rad. (0.79°)	5.24×10^{-2} rad. (3°)
Beamwidths { ϕ (elevation, 3 dB)	1.57×10^{-2} rad. (0.9°)	7.33×10^{-2} rad. (4.2°)
pulse width (τ)	0.2 μs	0.3 μs
PRF	4000 PPS	2000 PPS
IF Bandwidth	8 MHz @ .2 μs	5 MHz @ .3 μs
range resolution	30 m	45 m
RX sensitivity (MDS)	1×10^{-12} watts (-90 dBM)	1.585×10^{-13} watts (-98 dBM)
noise figure	14 dB	8.5 dB
$\lvert k' \rvert^2$ ice	0.209	0.209
$\lvert k' \rvert^2$ water	0.933	0.933
illuminated volume (@ R = 750 m)	2.07×10^3 m^3	5.51×10^4 m^3
antenna size (map)	40 x 20 in.	40 x 20 in.
polarization	linear (hor.) or circular	?

*provided in LTM 1MC-130E-1 Flight Manual and by Wright Patterson AFB/ENAMD

will vary or fluctuate especially if impedance variations or temperature changes within the feed and antenna system occur. The characteristics of the transmitter system may be monitored partially by bench tests ahead of time and by in-flight system measurements. The receiver gain stability needs also to be known. This should be obtainable mainly from bench tests if the data do not already exist.

Sampling Range and Recovery Time

It is desired to know the video channel time response in the vicinity of the transmitted pulse in order to determine the optimum gating point for L.W.C. measurements. Several effects may determine this gating point. The video is blanked to 1.8 μs (in the case of X-band) beyond the start of the pre-master trigger (video blanking) and modulator trigger pulses. The receiver output therefore cannot be gated prior to 270 meters range. Beyond this point, built in STC circuits affect the receiver gain and ringing responses may still occur from the trailing edge of the transmitted pulse or modulator feed through signal. Any other "clutter" returns occurring in the operating system output during this time are usually by multiple reflections in the feed, antenna system, or at any impedance discontinuities experienced by the RF energy. Therefore, the shape of the video output must be measured quantitatively. Measurements could be measured on an A-scope display (wide bandwidth oscilloscope) to determine the response shape and desired sample gate position where returns are sufficiently close to the noise.

Receiver Dynamic Range and Sensitivity

Once the sample gate positions have been obtained for Ka- and X-bands, the receiver dynamic range and sensitivity may be measured. The receivers have logarithmic IF responses and no automatic gain control (i.e., fixed gain) circuitry. Therefore, with a pulsed calibrated RF signal generator together with a wide-bandwidth-DC-coupled calibrated-oscilloscope measurement, the video output voltage (proportional to log power) could be measured. The injected RF calibration pulse would be delayed to the sample gate position desired. The RF signal source then could be step attenuated (monitored through a directional coupler and

calibrated RF power meter) starting from a level driving the receiver into saturation. Then the "linearity" of the log IF response could be checked together with the fixed gain receiver dynamic range by stepped attenuation until the noise level (MDS) is reached. Adjustments on the delay of the injected pulse should reproduce the slope of the STC circuitry (dB/μs) built into the receiver in the fixed STC "weather" mode of operation.

2.5.4 Data Recording System

The log amplitude-constant gain characteristic of the video channel is favorable for on-board gating, processing, and recording of the backscattered volumetric returns. The video voltage would undergo range gating, boxcarring (sample and hold), A/D conversion, buffer storage, and integration followed by integrator dumping, formatting and digital recording. Timing circuitry will be needed to keep track of integration counts, to provide time marks, and to identify the records on tape. The level of transmitter power (probably also variable with time) will also need to undergo similar processing and recording; however, the transmitted power measurement would require an A/D converter with a much smaller dynamic range. The exact configuration and specification of the equipment will depend on the outcome of preliminary tests. For example, if the receiver dynamic range is determined to be 100 dB, the size of the A/D converter required for better than ½ dB quantization of amplitude could be 8 bits (i.e., $2^n - 1 = 255$ levels at 0.392 dB/level). Care should also be taken to provide for system calibration recordings at frequent intervals prior to, during, and after mission flights (depending on system stability) to assure meaningful and repeatable reflectivity measurements.

2.5.5 Conclusions and Recommendations

The use of an on-board weather radar to collect airborne measurements of liquid water content appears to be feasible providing that equipment sensitivity and stability are proven to be adequate. The narrow pencil beam and high range resolution capability of the AN/APQ-122(V) 8 systems operating at Ka-band (∿33 GHz) and X-band (∿9.4 GHz) is particularly

suited to these requirements. The versatility of flying at designated heights and locations is desirable as is the availability for direct correlation with other on-board sensor data. The sensing of liquid water content, though indirect, is derivable through radar reflectivity back-scatter measurements in a volume ahead of the aircraft. The accuracy to which this can be accomplished depends to a large part on the care with which the systems are calibrated and also on the equipment design and stability.

It is believed that, through the recommended series of system checks, enough of the system characteristics may be determined to provide input to the design of interface equipment for an on-board digital recording system of pre-integrated data. It does not appear that any modification of the radar system will be required if the outcome of the preliminary tests proves favorable. The design of the interface equipment and recording system could proceed following an analysis of the preliminary data and the availability of the performance specifications.

2.6 Task 6 - Cloud and Precipitation Descriptions for Ten Case Studies

The synoptic and mesoscale cloud and precipitation patterns for nine cases at Wallops Island, Virginia and one case at Kwajalein were prepared. Cloud and precipitation cross sections were drawn using all the synoptic, satellite and special data which were available in the specific region. These analyses were prepared for AFGL scientists who used the data as part of their continuing research on the growth of precipitation.

3. REFERENCES

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Blood, D.W. and R.K. Crane, 1979: Assessment of Radar Parameters for Hydrometeor Scatter Measurement Using the ALCOR and TRADEX Radars at Kwajalein, Scientific Report No. 1, AFGL-TR-80-0031, ERT, Concord, Mass.

APPENDIX A

COMPUTER PROGRAMS OPERATING INSTRUCTIONS

LIST OF PROGRAMS AND TABLES

CONTENTS PAGE

TABLES

PROGRAM CLOUD7T

1. DESCRIPTION

Program CLOUD7T unpacks the ALCOR data tape (ADT) to creat a 7-track tape for the AFGL weather program. It can also be set up to generate a pulse listing giving the time to milliseconds of any pulse contained in the particular ALCOR data tape.

CLOUD7T produces one output tape known as the "weather" tape which can be processed in terms of the amplitude or the phase. It also can print a listing of pulse numbers along with their corresponding times.

The input to CLOUD7T consists of a 9-track ALCOR data tape.

2. DECK SET UP

2.1 CONTROL CARDS (CLOUD7T in UPDATE FILE under TUNG ID)

2.1.1 TO LIST PULSE INFORMATION

```
JOBNM,CM65000,T300,NT1,STMFB.     ACT NO.  NAME
VSN,TAPE1=MXXXXX/HD.
ATTACH,OLDPL,CLOUD7T,ID=TUNG.
UPDATE,N.
FTN,I=COMPILE,SL,PL=7777777.
REQUEST,TAPE1,HD,L,NT,NR.  (MXXXXX/NORING)
LDSET(PRESET=ZERO)
LGO.
7/8/9
*IDENT CHECK
*DELETE CLOUD7T.39
      LIST=1
*C CLOUD7T
7/8/9
DATA CARDS
6/7/8/9
```

(In the program CLOUD7T, line 39 reads LIST=0; to obtain a pulse list it must read LIST=1. The program is set up to list each tenth pulse. This may be altered by changing the counter in line 339 which is set at 10 but may be any number.)

2.1.2 TO CREAT 7-TRACK AMPLITUDE TAPE

```
JOBNM,CM65000,T500,NT1,MT1,STMFB.   ACT NO.  NAME
VSN,TAPE1=MXXXXX/HD.
VSN,TAPE15=LYCXXX.
ATTACH,OLDPL,CLOUD7T,ID=TUNG.
UPDATE(F)
FTN,I=COMPILE,SL,PL=7777777.
```

```
REQUEST,TAPE1,HD,L,NT,NR.   (MXXXXX/NORING)
REQUEST,TAPE15,HY,RING.   (LYCXXX/RING)
LDSET(PRESET=ZERO)
LGO.
7/8/9
*C CLOUD7T
7/8/9
DATA CARDS
6/7/8/9
(No alterations in the CLOUD7T program are needed)
```

2.1.3 TO CREAT 7-TRACK PHASE TAPE

```
JOBNM,CM65000,T900,NT1,MT1,STMFB.    ACT NO.   NAME
VSN,TAPE1=MXXXXX/HD.
VSN,TAPE15=LYCXXX.
ATTACH,OLDPL,CLOUD7T,ID=TUNG.
UPDATE,N.
FTN,I=COMPILE,SL,PL=7777777.
REQUEST,TAPE1,HD,L,NT,NR.    (MXXXXX/NORING)
REQUEST,TAPE15,HY,RING.    (LYCXXX/RING)
LDSET(PRESET=ZERO)
LGO.
7/8/9
*IDENT CHECK
*INSERT CLOUD7T.6
      DIMENSION IG(340)
*INSERT CLOUD7T.12
      DIMENSION XPTBL(255),XLPH(170),XRPH(170)
*INSERT CLOUD7T.79
      N=0
      DO 21 K=1,255
      N=N+1
   21 XPTBL(N)=XNBUF(K)
*INSERT CLOUD7T.301
      DO 38 K=1,170
      J=K + 170
      N=ILCPHA(K) + 128
      XLPH(K)=XPTBL(N)
      NCON(K)=XLPH(K)*100.
      M=IRCPHA(K) + 128
      XRPH(K)=XPTBL(M)
      NCON(J)=XRPH(K)*100.
   38 CONTINUE
*INSERT CLOUD7T.325
      CALL GBYTES(NOUT(1),NCON(1),1,14,1,170)
      CALL GBYTES(NOUT(1),IG(1),0,1,14,340)
      DO 80 I=1,340
      IF(IG(I).EQ.0) GO TO 80
      IG(I)=.NOT. NCON(I)
      CALL GBYTE (IG(I),NCON(I),46,14)
      NCON(I)=(-1)*NCON(I)
```

```
 80  CONTINUE
*INSERT CLOUD7T.480
      DIMENSION ISG(170)
*INSERT CLOUD7T.503
      NSKIP=NSO + 8*171
      CALL SKIP(NO,N,NSKIP)
      CALL GBYTES(IN(N),ISG(1),NSKIP,1,7,170)
      NSKIP=NSO + 8*171 + 1
      CALL SKIP(NO,N,NSKIP)
      CALL GBYTES(IN(N),IDAT(171),NSKIP,7,1,170)
      DO 23 IG=171,340
      NG=IG-170
  23  IDAT(IG)=(-1)**ISG(NG)*IDAT(IG)
*INSERT CLOUD7T.509
      NSKIP=NSO + 8*522
      CALL SKIP(NO,N,NSKIP)
      CALL GBYTES(IN(N),ISG(1),NSKIP,1,7,170)
      NSKIP=NSO + 8*522 + 1
      CALL SKIP(NO,N,NSKIP)
      CALL GBYTES(IN(N),IDAT(511),NSKIP,7,1,170)
      DO 24 IG=511,680
      NG=IG-250
  24  IDAT(IG)=(-1)**ISG(NG)*IDAT(IG)
*C CLOUD7T
7/8/9
DATA CARDS
6/7/8/9
```

2.2 INPUT DATA CARDS (for all CLOUD7T jobs)

Card #1 (2I10,2F10.3,10A4)

cc 1-10	(7200724)	ILNCH	Liftoff(Millis)
cc 11-20	(1)	NVALS	Number of start-stops
cc 33-40	(14.79)	GTESP	Inter Gate Spacing in meters
cc 41-80	ANT-3A	RUN ID	Up to 40 character title

Card #2 (8I10)

cc 1-10	(22401)	NSTART	Start Pulse # (right justified)
cc 11-20	(42400)	NSTOP	End Pulse # (right justified)

3. TIME AND MEMORY REQUIREMENTS

The 65k in octal memory is required to run the program. The 500 cp seconds is enough to creat the amplitude weather tape for 10000 pulses. It requires 900 cp seconds to creat the phase weather tape for 10000 pulses.

4. TAPES

TAPE1 is an INPUT tape consisting of a 9-track ALCOR data tape

from Lincoln Laboratory. The FORMAT of this tape is given in ALCOR DATA USERS AND RADAR OPERATORS MANUAL.

TAPE15 is an OUTPUT tape consisting of a 7-track 800 BPI weather tape. The FORMAT of this tape is listed in TABEL A-1. A maximum of 10000 pulses (records) can be stored on the regular 7-track tape.

5.SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

REFC(E,R,DEE,DRP)
READGS(IEOF,IERR)
HEADT(ISIG,IEQM)
CALIBR(XNBUF)
UNPACK(LIST)
SKIP(NO)
PPAGC(NO)
OPAGC(NO)
REAL 360(N,B)
CHAR 360(INT,N)
PACKK
GBYTES

PROGRAM PRHISEC

1. DESCRIPTION

Program PRHISEC processes the weather tape created from CLOUD7T to produce the line printer RHI plots of reentry weather scans. The scale of the plot is controlled by the data cards and it is possible to obtain several different plots with different altitude vs. range of the same data at the same time.

Input to the PRHISEC program includes one or more weather tapes previously obtained from the CLOUD7T program.

The PRHISEC program is set up to use a tracking gate of 52.5 (line 73) and a correlation factor of 82.5 (line 81). These values may change for different missions.

2. DECK SET UP

2.1 CONTROL CARDS (PRHISEC program in UPDATE FILE under TUNG ID)

```
JOBNM,T700,CM170000,MT2.       ACT NO.    NAME
VSN,TAPE1=LYCXXX.
VSN,TAPE2=LYCXXX.
ATTACH,OLDPL,PRHISEC,ID=TUNG,MR=1.
UPDATE(F)
FTN,I=COMPILE.
REQUEST,TAPE1,HY,L.    (LYCXXX/NORING)
REQUEST,TAPE2,HY,L.    (LYCXXX/NORING)
LDSET(PRESET=ZERO)
LGO.
REWIND,TAPE6.
COPYCF,TAPE6,OUTPUT.
REWIND,TAPE6.
COPYCF,TAPE6,OUTPUT.
7/8/9
*C PRHISEC
7/8/9
DATA CARDS
6/7/8/9
```

(This job is set up for the case where two weather tapes are needed as data input. If only one weather tape is needed only TAPE1 would be used with the VSN and REQUEST cards and the number of tapes would be changed on the JOB card. Currently PRHISEC is set up to handle no more than two weather tapes. Notice also that the output tape (TAPE6) is rewound and copied twice. This will result in two sets of plots being generated. If only one set is desired remove one REWIND and COPYCF of TAPE6.)

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM). For normal processing, one plot is generated with the desired Height vs. Range. The data cards are set up as follows:

```
 $PARAM
   DBMIN=0.,XMIN=42.0,XMAX=50.0,YMIN=2.00,YMAX=8.00,
   BTIME=0., NV=170., ETIME=0.,
   LASPLS=193768,
   NONPLS=0,
 $END
 $PARAM
   DBMIN=999.9,
 $END
```

The second set of NAMELIST is set to terminate the job. If desired, more plots with different Height and Range values can be generated by adding more sets of NAMELIST PARAM.

2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
DBMIN	R	Current not used, set to 1.0. DBMIN set to 999.9 for end of job.
XMIN	R	Minimum horizontal range of plot in km.
XMAX	R	Maximum horizontal range of plot in km.
YMIN	R	Minimum vertical height of plot in km.
YMAX	R	Maximum vertical height of plot in km.
BTIME	R	Time,in total seconds of day, at which to begin processing of scan.
ETIME	R	Time to end processing of scan, to process whole scan, set BTIME and ETIME to 0.
NV	I	Number of data values per tape record, current set to 170.
LASPLS	I	Last pulse number of scan, to end processing of data.
NONPLS	I	Pulse number of preceeding scan on tape, set to 0 if scan starts at beginning of tape.

3. TIME AND MEMORY REQUIREMENT

The 117k in octal of memory is required to run this program. Approximately 300 cp seconds processing time is required for one scan plot.

4. TAPES

One or two amplitude weather tapes (format in TABLE A-1) previously processed by CLOUD7T are needed as input to run this program. TAPE1 and TAPE2 are reserved for the input tapes. TAPE5 is for the NAMELIST input data cards. TAPE6 is for the printed output,the deck is set up to rewind and copy to the output file.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

READK(IEND)
GBYTE
GBYTES

PROGRAM TRADEX

1. DESCRIPTION

Program TRADEX was developed to process the AFGL SPECIAL TRADEX weather tape to generate line printer plots for RHI maps.

The input weather tape was specially created by Lincoln Laboratory for AFGL use. The header record of the tape provides the basic information for processing. The output plot contains a map of DBZ.

2. DECK SET UP

2.1 CONTROL CARDS

```
JOBNM,T300,CM120000,TP2.   ACT NO.   NAME
FTN,SL,PL=500000.
VSN,TAPE1=TR0880.
VSN,TAPE2=TR0940.
REQUEST,TAPE1,HY,NR.   (TR0880/NORING)
REQUEST,TAPE2,HY,NR.   (TR0940/NORING)
FILE(TAPE1,BT=I,RT=W,MRL=5130,MBL=5130)
FILE(TAPE2,BT=I,RT=W,MRL=5130,MBL=5130)
LDSET(FILES=TAPE1)
LDSET(FILES=TAPE2)
LDSET(PRESET=ZERO)
LGO.
REWIND,TAPE6.
COPYCF,TAPE6,OUTPUT.
7/8/9
SOURCE DECK
7/8/9
DATA CARDS
6/7/8/9
```

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM). For normal processing, one plot is generated with the desired height vs. range. The data cards are set up as follows:

```
 $PARAM
   DBMIN=1.0,XMIN=50.0,XMAX=80.0,YMIN=0.0,YMAX=20.0,
   BTIME=0.0,  ETIME=0.0,  NV=500,
 $END
 $PARAM
   DBMIN=999.9,
 $END
```

The second set of NAMELIST is set to terminate the job. If desired, more plots with different height and range scales can be

generated by adding more sets of NAMELIST PARAM.

2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
DBMIN	R	Current not used, set to 1.0. DBMIN set to 999.9 for end of job.
XMIN	R	Minimum horizontal range of plot in km.
XMAX	R	Maximum horizontal range of plot in km.
YMIN	R	Minimum vertical height of plot in km.
YMAX	R	Maximum vertical height of plot in km.
BTIME	R	Start time, set to 0.0. The header record of input tape will provide the tape start time in GMT total seconds.
ETIME	R	Stop time, set to 0.0. The header record of input tape will provide the tape stop time in GMT total seconds.
NV	I	Number of range gates per pulse (number of data values per tape record). Set to 500 for current use. 500 is the maximum array dimension in the program. The header record of the input tape will provide the value for each mission.

3. TIME AND MEMORY REQUIREMENT

The 120k in octal of memory is required to run this program. Approximately 300 cp seconds processing time is required for one scan plot.

4. TAPES

TAPE1 and TAPE2 are reserved as the input tapes called AFGL SPECIAL TRADEX weather tape (format in TABLE A-2) from Lincoln Laboratory. TAPE5 is for the NAMELIST input data. TAPE6 is for the printed output, the deck is set up to rewind TAPE6 and copy to the output file.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

READT(IEND)
GBYTE
GBYTES

PROGRAM APLOT AND TPLOT

1. DESCRIPTION

Programs APLOT and TPLOT were developed to process the vertical (zenith) scan radar data. They creat a plot from CALCOMP plotter to plot DBZ values vs. height in kilometers. Program APLOT processes the ALCOR radar weather tape created by the CLOUD7T program and program TPLOT processes the AFGL Special TRADEX weather tape provided by Lincoln Laboratory.

Input consists of the ALCOR or TRADEX weather tape. The output is an eleven inches by eleven inches online plot and a listing of height with DBZ values.

2. DECK SET UP

2.1 CONTROL CARDS

```
JOBNM,T700,MT2.         ACT NO.   NAME
FTN,SL,PL=50000.
VSN(TAPE3=LYCXXX)
VSN(TAPE4=LYCXXX)
REQUEST,TAPE3,HY,NR.   (LYCXXX/NORING)
REQUEST,TAPE4,HY,NR.   (LYCXXX/NORING)
COPYBF,TAPE3,TAPE1.
COPYBF,TAPE4,TAPE1.
REWIND,TAPE1.
REQUEST,PLOT,*Q.
ATTACH,PEN,ONLINEPEN.
LIBRARY,PEN.
DISPOSE,PLOT,*PL.
LDSET,FILES=TAPE1,PRESET=ZERO.
LGO.
7/8/9
SOURCE DECK
7/8/9
DATA CARDS
6/7/8/9
```

NOTE: Program TPLOT needs to insert a FILE card in contral cards.
FILE(TAPE1,BT=I,RT=W,MRL=5130,MBL=5130)

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM). They are set up as follows:

```
 $PARAM
   YMIN=5.0,YMAX=20.0,BTIME=0.,ETIME=0.,NV=170,
   LASPLS=XXXXXX,
 $END
```

```
$PARAM
  DBMIN=999.9,
$END
```

2.2.1 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
YMIN	R	Minimum vertical range of plot (km).
YMAX	R	Maximum vertical range of plot (km).
BTIME	R	Beginning time.
ETIME	R	End time.
NV	I	Number of data values per tape record, 170 for APLOT. Value changed of different mission for TPLOT, 500 is the maximum array dimension.
LASPLS	I	Last pulse number of data to be processed.
DBMIN	R	Set to 999.9 for end of processing.

3. TIME AND MEMORY REQUIREMENT

This program can be run under the default core. Approximately 600 cp seconds processing time is required to process an input tape containing 10000 pulses.

4. TAPES

TAPE1 is an input file copied from the input tapes (TAPE3 and TAPE4). For program APLOT, the input tapes are the ALCOR amplitude weather tapes previosly created from the CLOUD7T program (format in TABLE A-1). For program TPLOT, the input tapes are the special AFGL TRADEX weather tapes (format in TABLE A-2) provided by Lincoln Laboratory. TAPE5 is used for the NAMELIST input. TAPE6 is used for the printer output.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS

5.1 APLOT

READK(IEND)
GBYTE
GBYTES

5.2 TPLOT

READT(IEND)
GBYTE
GBYTES

PROGRAM MORT2

1. DESCRIPTION

The MORT2 program was modified from the PRHISEC program to get one second average information. The printout of this program is similar to the MOIST printout from Lincoln Laboratory. It contains time, range (km), altitude (km), azimuth (radians), elevation angle (radians), reflectivity (DBZ) and radar cross section for each second. If desired it can also be set up to creat an output tape in MOIST TAPE format.

2. DECK SET UP

2.1 CONTROL CARDS (MORT2 in UPDATE FILE under TUNG ID)

```
JOBNM,T300,CM120000,TP2.      ACT NO.   NAME
VSN,TAPE11=LYCXXX.
VSN,TAPE12=LYCXXX.
REQUEST,TAPE11,HY,NR.  (LYCXXX/NORING)
REQUEST,TAPE12,HY,NR.  (LYCXXX/NORING)
ATTACH,OLDPL,MORT2,ID=TUNG.
UPDATE(F)
FTN,I=COMPILE,SL,PL=7777777.
LDSET(PRESET=ZERO)
LGO.
7/8/9
*C MORT2
7/8/9
DATA CARDS
6/7/8/9
```

(This job is set up for the case where two weather tapes are needed but as many as ten tapes may be used as input data if needed. Whatever number input tapes are used, the first tape should be assigned TAPE11; the second TAPE12; etc., up to TAPE21, being certain to include a set of VSN and REQUEST cards for each and denoting the total number on the JOB card.)

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM). The data cards are set up as follows:

```
 $PARAM
 NTAPE = 2,
   DBMIN=1.0,XMIN=0.0,XMAX=90.0,YMIN=0.0,YMAX=20.0,
   BTIME=0.,  NV=170,  ETIME=0.,
   NONPLS=0,
   LASPLS=38232,
 $END
 $PARAM
   DBMIN=999.9,
```

$END

(The second set of NAMELIST is set to terminate the job.)

2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
NTAPE	I	Number of input tapes used in job.
DBMIN	R	Current not used, set to 1.0. Set to 999.9 for end of job.
XMIN	R	Minimum horizontal range of data (km).
XMAX	R	Maximum horizontal range of data (km).
YMIN	R	Minimum vertical height of data (km).
YMAX	R	Maximum vertical height of data (km).
BTIME	R	Time (total seconds of day) at which to begin processing.
ETIME	R	Time (total seconds of day) at which to end processing. To process all data set BTIME and ETIME to 0.
NV	I	Number of data values per tape record, current is set to 170.
NONPLS	I	Pulse number of preceeding data on tape (set to 0 if processing starts at beginning of tape).
LASPLS	I	Last pulse number of processing, to end processing of data.

3. TIME AND MEMORY REQUIREMENT

The 120k in octal of memory is required to run this program. Approximately 60 cp seconds processing time is required to run the data on one weather tape.

4. TAPES

TAPE11 to TAPE21 are reserved for the input tapes (format in TABLE A-1). TAPE3 is an output tape in MOIST TAPE format.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

READK (IEND)
GBYTE
GBYTES

PROGRAM PPOP

1. DESCRIPTION

Program PPOP processes the amplitude weather tape to produce time series maps for each second of time. The program creates four output sets consisting of: the mapping for the amplitude of principal polarization (PP); the mapping for the amplitude of orthogonal polarization (OP); the mapping for the difference between the principal and orthogonal polarization (PP-OP); and the listing for the height (km) of the first and last range gate used. PPOP uses a six-gate averaging scheme with the last (29th) value being a two-gate average. Limitations in page size (OUTPUT) with intent on obtaining the smallest number of gates to be averaged led to this averaging scheme. The values of principal and orthogonal polarization and their difference are mapped in tenths DBZ with their appropriate sign (blank equals positive).

2. DECK SET UP

2.1 CONTROL CARDS (PPOP in UPDATE FILE under TUNG ID)

```
JOBNM,T500,CM120000,TP1.        ACT NO.    NAME
VSN,TAPE1=LYCXXX.
ATTACH,OLDPL,PPOP,ID=TUNG.
UPDATE(F)
FTN,I=COMPILE,SL,PL=7777777.
REQUEST,TAPE1,HY,NR.  (LYCXXX/NORING)
LDSET(PRESET=ZERO)
LGO.
REWIND,TAPE6.
COPY,TAPE6,OUTPUT.
REWIND,TAPE7.
COPY,TAPE7,OUTPUT.
REWIND,TAPE8.
COPY,TAPE8,OUTPUT.
REWIND,TAPE3.
COPY,TAPE3,OUTPUT.
7/8/9
*C PPOP
7/8/9
DATA CARDS
6/7/8/9
```

(If a second tape is needed as input it would be designated TAPE2 and a VSN and REQUEST card for TAPE2 would be added following the present VSN and REQUEST cards. Also, the number of tapes indicated on the JOB card would be changed to 2.)

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM) and they are set up as follows:

```
$PARAM
  DBMIN=1.0,XMIN=0.0,XMAX=90.0,YMIN=0.0,YMAX=20.0,
  BTIME=0.,  NV=170,  ETIME=0.,
  IPASS=7,
  NONPLS=0,
  LASPLS=44800,
$END
$PARAM
  DBMIN=999.9,
$END
```

2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
DBMIN	R	Current not used, set to 1.0. DBMIN set to 999.9 for end of job.
XMIN	R	Minimum horizontal range of data (km).
XMAX	R	Maximum horizontal range of data (km).
YMIN	R	Minimum vertical height of data (km).
YMAX	R	Maximum vertical height of data (km).
BTIME	R	Time, in total seconds of day, at which to begin processing scan.
ETIME	R	Time to end processing of data, to process all of data set BTIME and ETIME to 0.
NV	I	Number of data values per tape record, current set at 170.
IPASS	I	Identification number of pass working on.
NONPLS	I	Pulse number of preceeding data on tape, set to 0 if data starts at beginning of tape.
LASPLS	I	Last pulse number of data, to end processing of data.

3. TIME AND MEMORY REQUIREMENT

The 120k in octal of memory is required to run this program. Approximately 500 cp seconds processing time is needed to process two input tapes (each about 10000 pulses) of data.

4. TAPES

TAPE1 and TAPE2 are reserved for input tapes (format in TABLE A-1).

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

READK (IEND)
GBYTE
GBYTES

PROGRAM PPOPF

1. DESCRIPTION

The PPOPF program processes the phase weather tape to produce an every second phase difference listing. It lists the average phase difference in radians for all 170 gates along with tracking gate (52) information. The tracking gate information consists of: the time to milliseconds; the true range (km); the azimuth (radians); the elevation angle (radians); the altitude (km); the range with respect to the X-axis (km); the range with respect to the Y-axis (km); and the phase difference. The 170 values listed are the one second phase differences of the 170 range gates.

Input to the PPOPF program consists of one or two phase weather tapes previously processed by the CLOUD7T program.

Output from the PPOPF program consists of a listing of the phase difference for all 170 gates of each 200 pulse average or, one second of time.

2. DECK SET UP

2.1 CONTROL CARDS (PPOPF in UPDATE FILE under TUNG ID)

```
JOBNM,T500,CM120000,TP1.     ACT NO.    NAME
VSN,TAPE1=LYCXXX.
ATTACH,OLDPL,PPOPF,ID=TUNG.
UPDATE(F)
FTN,I=COMPILE,SL,PL=7777777.
REQUEST,TAPE1,HY,NR.  (LYCXXX/NORING)
LDSET(PRESET=ZERO)
LGO.
7/8/9
*C PPOPF
7/8/9
DATA CARDS
6/7/8/9
```

(If a second tape is needed as input it would be designated TAPE2 and a VSN and REQUEST card for TAPE2 would be added following the present VSN and REQUEST cards. Also, the number of tapes indicated on the JOB card would be changed to 2.)

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM) and they are set up as follows:

```
 $PARAM
   DBMIN=1.0,XMIN=0.0,XMAX=90.0,YMIN=0.0,YMAX=20.0,
   BTIME=0.,   NV=170,   ETIME=0.,
   NONPLS=0,
```

```
  LASPLS=44800,
 $END
 $PARAM
  DBMIN=999.9,
 $END
```

2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
DBMIN	R	Current not used, set to 1.0. DBMIN set to 999.9 for end of job.
XMIN	R	Minimum horizontal range of data (km).
XMAX	R	Maximum horizontal range of data (km).
YMIN	R	Minimum vertical height of data (km).
YMAX	R	Maximum vertical height of data (km).
BTIME	R	Time, in total seconds of day, at which to begin processing scan.
ETIME	R	Time to end processing of data, to process all of data set BTIME and ETIME to 0.
NV	I	Number of data values per tape record, current set at 170.
NONPLS	I	Pulse number of preceeding data on tape, set to 0 if data starts at beginning of tape.
LASPLS	I	Last pulse number of data, to end processing of data.

3. TIME AND MEMORY REQUIREMENT

The 120k in octal of memory is required to run this program. Approximately 500 cp seconds processing time is needed to process two input tapes (each about 10000 pulses) of data.

4. TAPES

TAPE1 and TAPE2 are reserved for input tapes (format in TABLE A-1).

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

READK (IEND)
GBYTE
GBYTES

PROGRAM PPOPX

1. DESCRIPTION

Program PPOPX was developed to improve the data processing techniques by using polarization measurements of hydrometeors to process ALCOR data tapes. Four final terms for each range gate of every second were computed and processed to generate the RHI maps. These four terms are reflectivity in DBZ, cancellation in DB, correlation in percent and orientation in tens of degrees.

The input to program PPOPX include the amplitude weather tape and the phase weather tape both created by the CLOUD7T program. The output consists of the four maps of the four terms mapped for every second.

2. DECK SET UP

2.1 CONTROL CARDS (PPOPX program in UPDATE FILE under TUNG ID)

```
JOBNM,CM140000,T1000,TP2.     ACT NO.    NAME
VSN,TAPE1=LYCXXX.
VSN,TAPE11=LYCXXX.
REQUEST,TAPE1,HY,NR.  (LYCXXX/NORING)
REQUEST,TAPE11,HY,NR.  (LYCXXX/NORING)
ATTACH,OLDPL,PPOPX,ID=TUNG.
UPDATE(F)
FTN,I=COMPILE,SL,PL=7777777.
LDSET(PRESET=ZERO)
LGO.
7/8/9
*C PPOPX
7/8/9
DATA CARDS
6/7/8/9
```

(TAPE1 is the amplitude weather tape and TAPE11 is the phase weather tape.)

2.2 INPUT DATA CARDS

The input data cards are in NAMELIST form ($PARAM) and the data cards are set up as follows:

```
 $PARAM
   DBMIN=1.0,XMIN=63.0,XMAX=73.0,YMIN=7.5,YMAX=12.5,
   BTIME=0.,  NV=170,  ETIME=0.,
   NONPLS=0,
   LASPLS=33400,
 $END
 $PARAM
   DBMIN=999.9,
 $END
```

The second set of NAMELIST is set to terminate the job. Due to the rather lengthy size of the run it is not recommended to add on any additional plots.

2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
DBMIN	R	Current not used, set to 1.0. DBMIN set to 999.9 for end of job.
XMIN	R	Minimum horizontal range of plot in km.
XMAX	R	Maximum horizontal range of plot in km.
YMIN	R	Minimum vertical height of plot in km.
YMAX	R	Maximum vertical height of plot in km.
BTIME	R	Time, in total seconds of day, at which to begin processing of scan.
ETIME	R	Time, to end processing of scan, to process whole scan, set BTIME and ETIME to 0.
NV	I	Number of data values per tape record, current set to 170.
LASPLS	I	Last pulse number of scan, to end processing of data.
NONPLS	I	Pulse number of preceeding scan on tape set to 0 if scan starts at beginning of tape.

3. TIME AND MEMORY REQUIREMENTS

The 140k in octal of memory is required to run this job. Approximately 1000 cp seconds processing time is required for one set of plots involving about 10000 pulses on the weather tapes.

4. TAPES

TAPE1 is reserved to input the amplitude weather tape and TAPE11 is reserved to input the phase weather tape. The format of these tapes are given in TABLE A-1. TAPE 5 is used for the NAMELIST input. TAPE 6 is used for the printer output by rewinding TAPE 6 and copying to ouput file.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS

READK(IEND)
AMP
PHASE
SECSUM
PLSET
RHPLOT(IJK)
GBYTE
GBYTES

PROGRAM WRHISEC FOR WALLOPS ISLAND DATA

1. DESCRIPTION

Program WRHISEC produces line printer plots of radar RHI scans for Wallops Island data. This program has been modified for years. All the modifications are listed in program comments. The current version was modified in july 1977 to include vertical cutoff for rain attenuation.

2. DECK SET UP

2.1 CONTROL CARDS

```
JOBNM,CM107000,T100,TP1.                    ACT.NO.     NAME
FTN,SL,PL=50000.
VSN,TAPE2=W43292.
REQUEST,TAPE2,HI,S.
COPYBF,TAPE2,TAPE1,1.
SKIPF,TAPE2,7,17,B.
COPYBF,TAPE2,TAPE1,1.
REWIND,TAPE1.
UNLOAD,TAPE2.
RETURN,TAPE2.
FILE(TAPE1,BT=K,RT=S,MBL=1540,MRL=1540,RB=1,EO=T)
LDSET,FILES=TAPE1,PRESET=ZERO.
LGO.
REWIND,TAPE6.
COPYCF,TAPE6,OUTPUT.
REWIND,TAPE6.
COPYCF,TAPE6,OUTPUT.
7/8/9
SOURCE DECK
7/8/9
DATA CARDS
6/7/8/9
```

2.2 INPUT DATA CARDS

The structure of the input cards is ordered as follows:

Set 1	Title card
Set 2	NAMELIST CORR
Set 3	N set NAMELIST PARAM (N is number of files to be processed + 1)

2.2.1 TITLE CARD (8A10)

The TITLE CARD contains the data aquisition date and the begin and end time of the first and last files on the tape.

2.2.2 NAMELIST CORR VARIABLES

NAME	TYPE	MEANING
GLC	R	Glover constant used in computing rainfall attenuation, set to 0.0 for runs without rainfall attenuation.
LMBDA	R	Used in computing oxygen attenuation, set to 0.0 for runs without oxygen attenuation.
AB	R	Constant for Z-R relation.
BB	R	Constant for Z-R relation.
RAINHT	R	Vertical height (KM) at and above which correction for rain attenuation stops. If RHI is completely rain attenuated, set RAINHT to YMAX.

2.2.3 NAMELIST PARAM VARIABLES

NAME	TYPE	MEANING
DBMIN	R	Minimum DB of mapping, normally set to 41.0, DBMIN set to 999.9 for end of processing.
XMIN	R	Minimum horizontal range of plot (KM).
XMAX	R	Maximum horizontal range of plot (KM).
YMIN	R	Minimum vertical range of plot (KM), normally set to 0.0.
YMAX	R	Maximum vertical range of plot (KM), normally set to 12.0.
BTIME	R	Beginning time of data to be processed, in form DDD.HHMMSS where DDD is julian day.
ETIME	R	End time of date to be processed. To process all data in the file, set BTIME and ETIME to 0.0.
CEL	R	Elevation angle correction, set to 0.0 for no correction.
NV	I	Number of data points per record, provided by an information sheet called DIGITAL TAPE LOG.
CWA	R	Cell constant, set to 0.5053.
CW1	R	Cell width in microsecs, provided by DIGITAL TAPE LOG.
NA	I	Number of cells integrated, provided by DIGITAL TAPE LOG.
NORM	I	Range normalization control, set to 0.0 for no range normalized data, set to nonzero value for range normalized data, provided by DIGITAL TAPE LOG.
MINV	I	Minimum data value (bit count) for noise level cutoff from calibration curve.
MAXV	I	Maximum data value (bit count) above which all data is in error from calibration curve, normally set to 255.
ICUTOF	I	Data value (bit count) below which leftmost portion of calibration curve begins to deviate from remainder of curve.
FA	R	Intercept of calibration curve on DBM axis.

FALEFT	R	Intercept of leftmost part of calibration curve on DBM axis, add +115 DBM to plot DBM values to obtain correct intercept value.
FM	R	Slope of calibration curve.
FMLEFT	R	Slope of leftmost part of calibration curve, slope defined as : DELTA DBM/DELTA BIT COUNT.
NVAL	R	Currently not used, set to 60*0.0.

3. TIME AND MEMORY REQUIREMENT

The 107K memory in octal is required to run this program. Approximately 40 cp seconds processing time is required for each file.

4. TAPES

TAPE1 is an input tape, it is a binary tape, odd parity. There is more than one file per tape, each file has to be processed separately. The deck is set up to copy TAPE1 to the tape to skip bad files. TAPE5 is for punched input data. TAPE6 is for printed output, the deck is set up to rewind TAPE6 and copy it to the output file. The structure and information of the input tape is provided by a sheet called the DIGITAL TAPE LOG. TABLE A-3 is a sample sheet of the DIGITAL TAPE LOG.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

```
ATNCOR (NEWVLC,CL,SINEL,RNG,DY,YY)
CONVRT (IVAL,NEWVLC)
READW (IEOF)
RNCGEN (CW1,NA,ISAVE)
```

PROGRAM IWCCI

1. DESCRIPTION

Program IWCCI was modified from program LWC which was used in the AFGL-2 USSR eleven station analysis. Both programs were developed to read AFGL-2 meteorological data cards. Program IWCCI classifies Cirrus clouds according to their amount, from 0 to 10 tenths coverage; by type, whether single or multi-layer and whether associated with Cumulonimbus clouds or not; and also lists their base, top, liquid water content and thickness (top-base). It also produces a statistical table in which the monthly number of occurrances by time (each three hour period of day) and by sky cover amount (0 to 10 tenths) and the summation of each is listed. The total number of clear cases is also tabulated by month and listed beneath the table.

Input to the IWCCI program consists of the meteorological data cards generated from the AFGL-2 eleven station analysis or similar analysis.

Output from the IWCCI program consists of a printout comprised of twelve tables. Tables one to eleven give Cirrus cloud information based on Cirrus cloud sky coverage from 0 to 10 tenths and the twelfth table lists the total monthly occurrance of each Cirrus event.

2. DECK SET UP

2.1 CONTROL CARDS (IWCCI in UPDATE FILE under TUNG ID)

```
JOBNM,CM105000,T10.     ACT NO.    NAME
ATTACH,OLDPL,IWCCI,ID=TUNG.
UPDATE,N.
FTN,I=COMPILE,SL,PL=7777777.
LDSET(PRESET=ZERO)
LGO.
7/8/9
*IDENT CHECK
*DELETE IWCCI.29
      MTH=1
*C IWCCI
7/8/9
METEOROLOGICAL DATA CARDS
6/7/8/9
```

(MTH represents the month of data being processed with 1=JAN, 2=FEB, etc.. Only one month of data may be processed at a time and only one station may be processed at a time. The month designated by MTH must be the same as the month of meteorological data cards being processed.)

2.2 INPUT DATA CARDS

The input data cards consist of the meteorological data cards. The format for the meteorological data cards is given in TABLE A-4.

3. TIME AND MEMORY REQUIREMENT

The 105k in octal of memory is required to run this program. Approximately 10 cp seconds processing time is required to process one month of data for one station.

4. TAPES

TAPE3 is used to store ESI profiles which is not used in this version of the program. TAPE5 is reserved for the input data cards (format in TABLE A-4). TAPE6 to TAPE8 are reserved for the statistics tables output which are not used in this version. TAPE11 to TAPE21 are used to store and output eleven sets of data classified by sky coverage.

5. SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED

```
REARAY(Y1,Y2,XX,Y4,Y5,Y6,KK)
ZERO(Y1,Y2,XX,Y4,Y5,Y6,KK)
STATIS(NO,IJK)
MEDIAN(I,J)
INTZ(B,L,X,Y,Z1,Z2,Z)
```

TABLE A-1

AFGL ALCOR WEATHER TAPE

The format and contents of the AFGL ALCOR Amplitude or Phase weather tape to be generated on the CDC-6600 is described below. The tape will be 7-track, 800 BPI, Fortran unformatted.

The first record on the tape will be a header record and all others will be data records. All values are store in integer form, a factor is provided for division.

HEADER RECORD

NAME	TYPE	MCON ARRAY	WORD	DESCRIPTION
IDESCR(1)	EBCDIC	1	1	40 characters from input card
-		-	-	
IDESCR(10)		10	10	
ITBAND	FX	11	11	=0 (NB), =1 (WB)
ITREEL	FX	12	12	Reel number
IMTH	FX	13	13	Month
IDAY	FX	14	14	Day
IYR	FX	15	15	Year (last two digits)
ILNCH	FX	16	16	Lift off (millisecs)
IPULST	FX	17	17	First pulse No. on tape(INPUT)
IPULSP	FX	18	18	Last pulse NO. on tape(INPUT)
TRKGTE	FX	19	19	ALCOR tracking gate *100
GTESPC	FX	20	20	Intergate spacing (m) *100
-		21-	21-	Spares

DATA RECORD

NAME	TYPE	NCON ARRAY	WORD	DESCRIPTION
RCSLC(1)	FX	1	1	LC Amplitude or Phase (db) *100
RCSLC(2)	FX	2	1	For Amplitude,if no sign assume
RCSLC(3)	FX	3	1	negtive numbers.
RCSLC(4)	FX	4	1	For Phase,the left-most bit of
-		-	-	the 15 bit integer is sign bit.
RCSLC(169)	FX	169	43	
RCSLC(170)	FX	170	43	
RCSRC(1)	FX	171	43	RC Amplitude or Phase (db) *100
RCSRC(2)	FX	172	43	
-		-	-	
RCSRC(170)	FX	340	85	
GMT	FX	341	86	GMT (Seconds) *1000
-		342	86	
TAL	FX	343	86	TAL (seconds) *1000
-		344	86	
NUMPRI	FX	345	87	Pulse number
IHRS	FX	346	87	Hours

NAME	TYPE	NCON ARRAY	WORD	DESCRIPTION
IMIN	FX	347	87	Minutes
ISEC	FX	348	87	Seconds
IFRAC	FX	349	88	Milliseconds
RANGE	FX	350	88	range to tracking gate (m) *10
AZ	FX	351	88	Azimuth (deg) *100
EL	FX	352	88	Elevation (deg) *100
CALT	FX	353	89	Altitude (m) *10
-	FX	-	-	Spares
-	FX	400	100	Spare

NOTE : In data records, the array NCON are packed four to each CDC word.

TABLE A-2

AFGL SPECIAL TRADEX WEATHER TAPE

The format and contents of a special TRADEX S-narrow band chip calibrated weather tape to be generated on CDC-6600 for AFGL is described below. The tape will be 7-track, 800 BPI, Fortran unformatted, containing standard SCOPE records.

The first record on the tape will be a header record and all others will be data records. The header record will contain information describing the contents of the tape. The data record will contain metric information updated every 0.1 s and one pulse of calibrated signature data.

HEADER RECORD (20 WORDS)

WORD	DESCRIPTION	TYPE
1	Polarization (9=PP, 10=OP)	Integer
2	No. of range gates per pulse	Integer
3	Intergate spacing (m)	Real
4-10	Tape description	Display code
11	Tape start (GMT total s)	Integer, LSB is 0.0001
12	Tape stop (GMT total s)	Integer, LSB is 0.0001
13	Gate number of tracking gate	Integer
14-20	Spares	

DATA RECORD

WORD	DESCRIPTION	TYPE
1	Pulse time (GMT total s)	Integer, LBS is 0.0001
2	Range (m)	Real
3	Azimuth (deg)	Real
4	Elevation (deg)	Real
5	Time (GMT total s) associated with R, AZ, and EL	Integer, LBS IS 0.0001
6-10	Spares	
11-	Rader cross section for all gates of the pulse packed four to each CDC-6600 word. The left-most bit of the 15 bit integer is the sign bit. Nagative integers are in one's complement form.	Integer, LSB is 0.1 dbsm

TABLE A-3

AFCRL WEATHER RADAR SITE
SUDBURY, MASS.

DIGITAL TAPE LOG

DIGITAL TAPE

Date Digitized 19 APR 76
Tape No.
Program TATER SHOT
Data Digitized RHI's
Data Points Per Record 500
Packing Density 556 BPI
Approx. No. of Records This Tape 5000

ANALOG TAPE

Date 27/28 MAR 76 Tape No. 76-23+24
Integrator No. 1
Pulse Pair Proc. No. —
Cell Width 1.008 µsec.
Cells Integrated 4
No. of Cells 568
No. of Sweeps Integrated 128
AGC Sweeps Integrated —
Receiver Noise Correction Yes ✓ No.
Range Norm. Curve Yes ✓ No.
Site SPANDAR

	TIME Start	Stop	EOF No.	Azimuth	Elevation	Remarks
28 MAR	88 00 11 01	88 00 11 24	1	100°	0-22°	
27 MAR	87 22 27 17	87 22 28 03	2		0-45°	
	22 46 29	22 47 13	3		0-45°	
	22 56 01	22 56 55	4		45-0°	Shot Time
	22 57 02	22 57 50	5		0-45°	Shot Time
	22 57 08	22 58 49	6		45-0°	Shot Time
	23 00 23	23 01 08	7		45-0°	
	23 03 20	23 04 08	8		45-0°	
	23 11 12	23 12 00	9		0-45°	
	23 19 03	23 19 51	10		0-45°	

TABLE A-4

METEOROLOGICAL DATA CARD FORMAT

COLUMNS	SAMPLE	DATA
1		Blank.
2-4	155	Location (station number, 155 = Moscow).
5-6	01	Day.
7-9	FEB	Month.
10-11	73	Year.
12-13	00	Time (00Z, 03Z, etc.).
14-17	0200	Area representativeness (200 nm in the N-S direction).
18-21	0120	Area representativeness (120 nm in the E-W direction).
22		Blank.
23	2	Identifier (2 = precip. water content in g/m**3; 1 = liquid or cloud water content in g/m**3; blank = clear).
24-27	01.4	Altitude (lower) of layer in thousands of feet (1400 feet).
28-31	05.0	Altitude (upper) of layer in thousands of feet (5000 feet).
32-33	10	Coverage in tenths (10/10).
34-35	TYPE	Type of precipitation or cloud (I.C. = ice crystal; S.S. = small snow; L.S. = large snow; RN. = rain with cloud type symbols those normally used).
36-40	0.100	Water content in g/m**3.
41-58		Second and third sets of data;
59-76		follow same format as 23-40.

NOTE:

If more than three sets of data are present during one profile, columns 1-22 are repeated on the following card(s) until all data is tabulated.

APPENDIX B

THE WEATHER CORRELATION RUNS OF
26 JUNE 1979 AT KWAJALEIN

David W. Blood

APPENDIX B

THE WEATHER CORRELATION RUNS OF
26 JUNE 1979 AT KWAJALEIN

1. Introduction

The weather correlation test series, KMR 4028, was conducted at Kwajalein Atoll, Kwajalein Missile Range on 26 June 1979. The purpose of the linked-radar/aircraft experiment was to collect data simultaneously, both by radar backscatter and by on-board aircraft measurements of the hydrometeor type and size distribution for correlation and calibration purposes. The tests were conducted to establish liquid water versus reflectivity relationships for a re-entry mission where radar-only data would be available. The series consisted of several runs (numbered 1 through 5) during the period of 0200 and 0400 GMT on the GMT date indicated where the Lear-jet aircraft flew different passes through weather storm cells while being tracked by an MPS-36 radar on Kwajalein, Is. at the Atoll. The Lincoln KREMS radars (ALCOR, C-band and TRADEX, S-band) were linked to the tracking radar and designated to collect backscatter returns from a cell volume immediately (3 km) ahead of the aircraft. The radar data were later processed off-line by a program called "moist" to calculate quantities related to atmospheric moisture content. This data, in turn, may be correlated against the aircraft on-board measurements to check the calibration constants and procedures used in converting radar backscattering cross sections to radar reflectivity factor, Z, which in turn is relatable to the moisture content within the range cell of question. Ideally, the two backscattering radars, having roughly the same resolution (with the waveforms used for this type of measurement), will have agreement to within about 1 dB of each other in terms of the backscattered Z levels. On this series, however, considerable disagreement was experienced on some of the runs and in certain regions of a particular run amounting to differences at times up to 25 dB between the two radars. This rendered questionable the use of either radar measurements at these times. In this report, only the radar operations and results will be discussed.

The operations consisted of four runs in the vicinity south and slightly east of Kwajalein, Is. at altitudes of 4500 to 4800 meters and

one run north-east of Roi-Namur, Is. at altitudes of 2200 to 2600 meters. Correspondingly, the KREMS radars were directed to look toward the south-east at ranges varying from 75 to 115 kms (elevations from 2.9 to 1.8 degrees) for run nos. 1 to 4 and toward the northeast at ranges varying from 15 to 22 kms (elevations from 8.5 to 6 degrees) on run no. 5. Figure 1 shows the location of the tracks in terms of radar coordinates (slant range and azimuth) from Roi-Namur. It appears that for the most part, the radar operations were nominal in the linked mode in following the designated tracks and in monitoring data within the dynamic range of the radar receivers through the real-time attenuation switching algorithms. There were certain losses of tracking (and of maintaining locked radars) at the mid-portion of run no. 1, for example, and at the beginning and end of run no. 5 (dashed traces on Figure 1). Since these regions may easily be edited out of the acceptable data sets no further discussion will be devoted to these limited difficulties.

The TRADEX S-band radar antenna system was operating in a 45° linear polarization configuration as opposed to the circular polarization configuration previously used and also used on ALCOR. This caused no unusual difficulties in terms of calibration or antenna patterns, as initially suspected for the radar disagreements. The goodness of radar calibrations was verified by (20 inch) sphere calibrations conducted one day after the weather correlation runs. Both TRADEX and ALCOR obtained sphere back-scattered RCS measurements agreeing with the theoretical optical RCS value of -7.0 dBsm to within ±1 dB. The polarization isolation between the principal (PP) and opposite (OP) polarization received channels on these high signal-to-noise (S/N) checks exceeded 27 dB on both radars. Antenna pattern checks with the linearly polarized TRADEX S-band configuration were requested and they indicated no change from the earlier circular configuration patterns. The question remained, therefore, as to why the large discrepancy in backscattered dBZ values between the two radars supposedly trained upon the same weather cell.

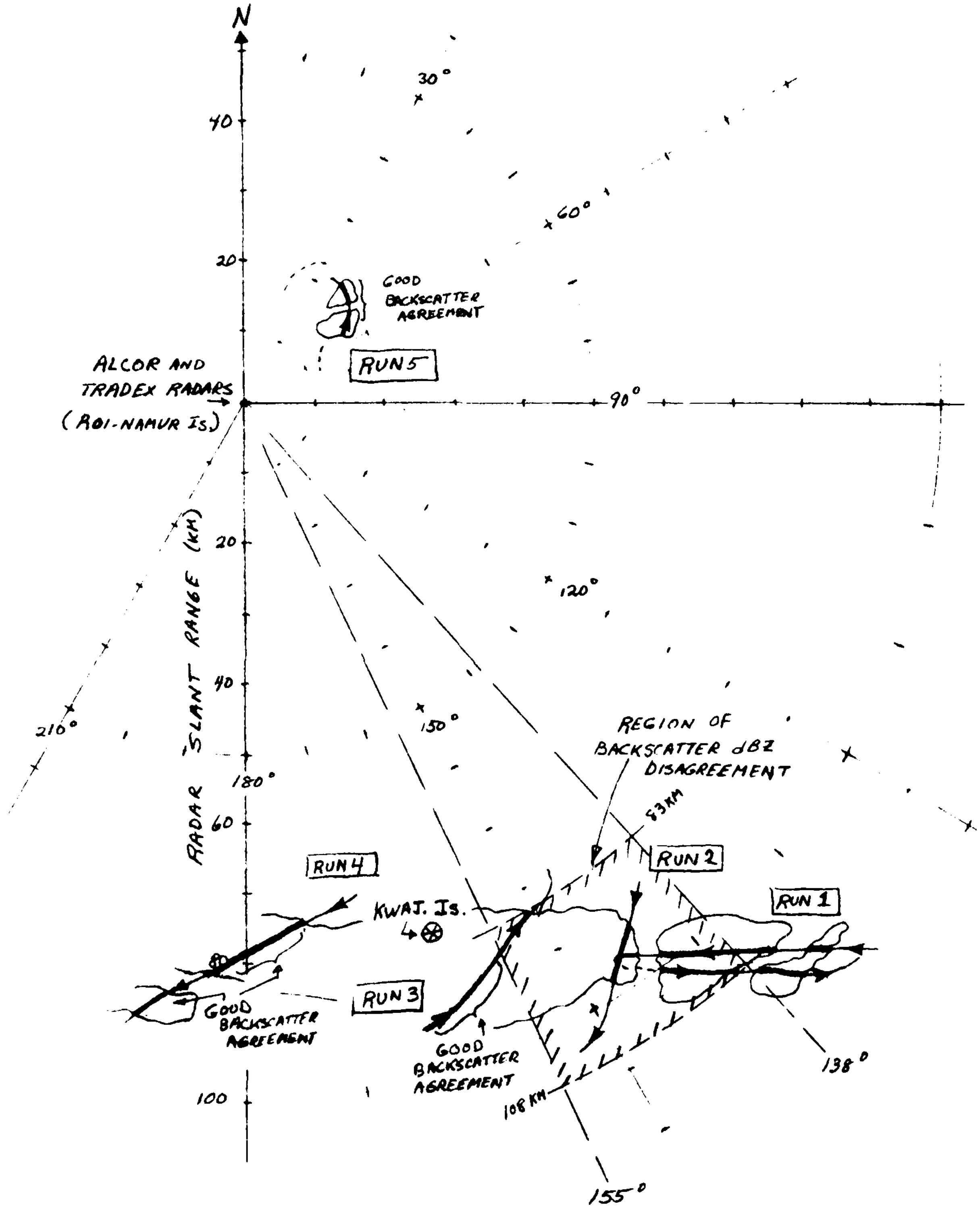


Figure 1 Weather correlation runs, June 26, 1979

2. Observations on June 26, 1979

Figures 2 through 6 show the radar measurements in dBZ for runs no. 1 through 5 respectively. The ALCOR measurements (dashed) may be compared with TRADEX (solid) for each of these runs. It is evident that a large departure occurred between TRADEX and ALCOR during all portions of runs 1 and 2 and during the latter portion only on run 3. Corresponding to the dBZ plots, the received polarization ratio (principal to opposite, PP-OP in dB) is shown at the bottom of each figure. During the periods of backscatter disagreement the polarization ratios were also generally poorer than would be expected for rain scatter.

As a result of the observed polarization ratio degradation and an examination of the theoretical ratio to be expected from rain, a set of editing rules were developed for selecting out the usable data as indicated in Table 1.

Several other observations may be made from the radar data. The early portion of run no. 3, run no. 4 and run no. 5 all show favorable backscatter agreement (to within 6 dB) between TRADEX and ALCOR. At these times the polarization ratios were generally high (exceeding 18 dB) when signal-to-noise conditions were high. When agreement was favorable on runs 3 and 4, there still remained a 6 dB difference between TRADEX and ALCOR, ALCOR being lower. Finally, on run 5, much nearer the KREMS radars the dBZ levels agree very well to within ± a few dB as has been observed on other normal missions.

3. Possible Explanation of Results

It is believed that the observed different dBZ levels and PP/OP degradation are not the result of a single cause but a combination of effects. The effects all may be classified as propagation effects, however, as opposed to hardware or tracking problems. There are several reasons to believe that the radars were operating correctly. The sphere calibrations cited earlier strongly suggest no major biases in the radar set-up.

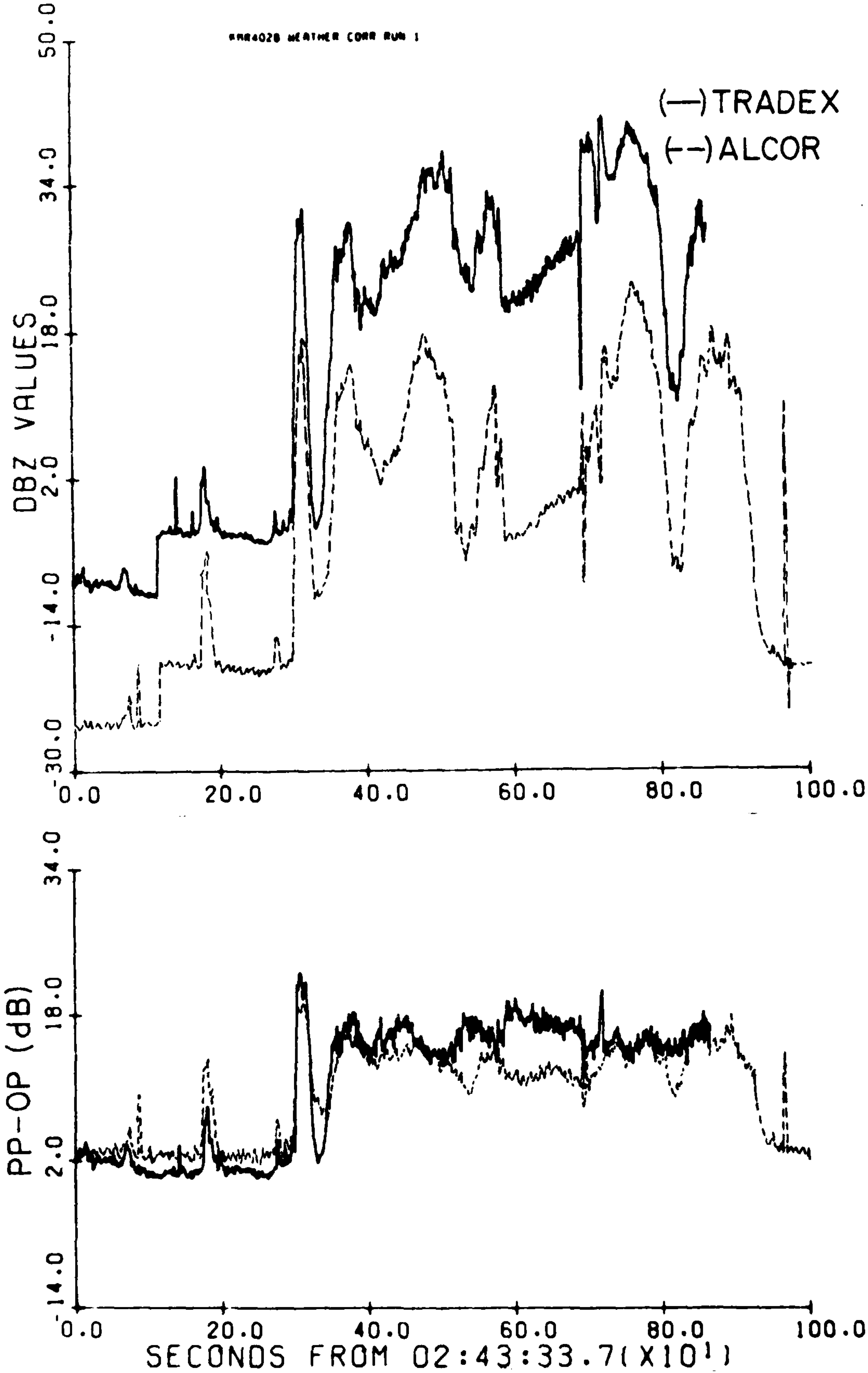


Figure 2 Radar comparisons for Run 1

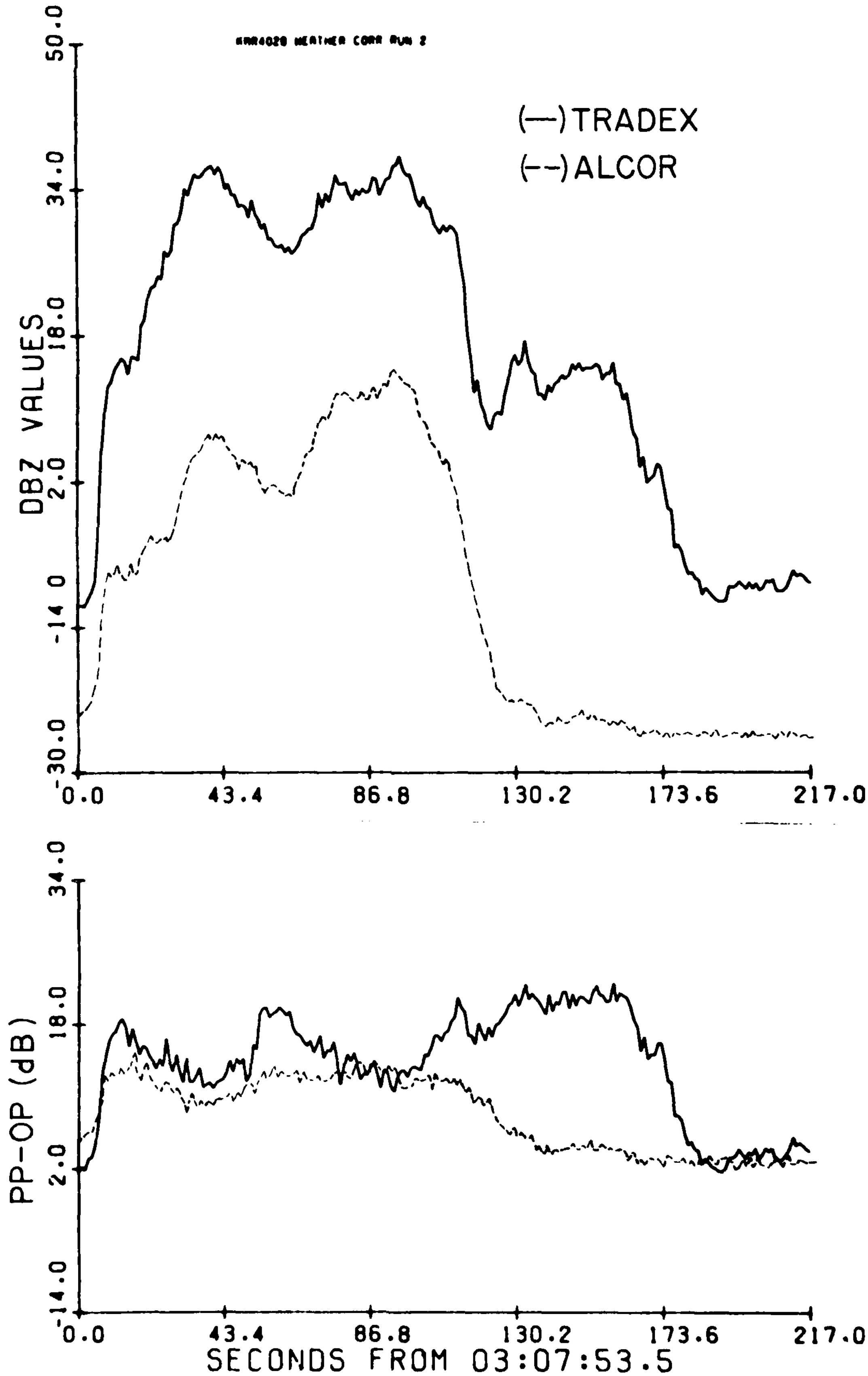


Figure 3 Radar comparisons for Run 2

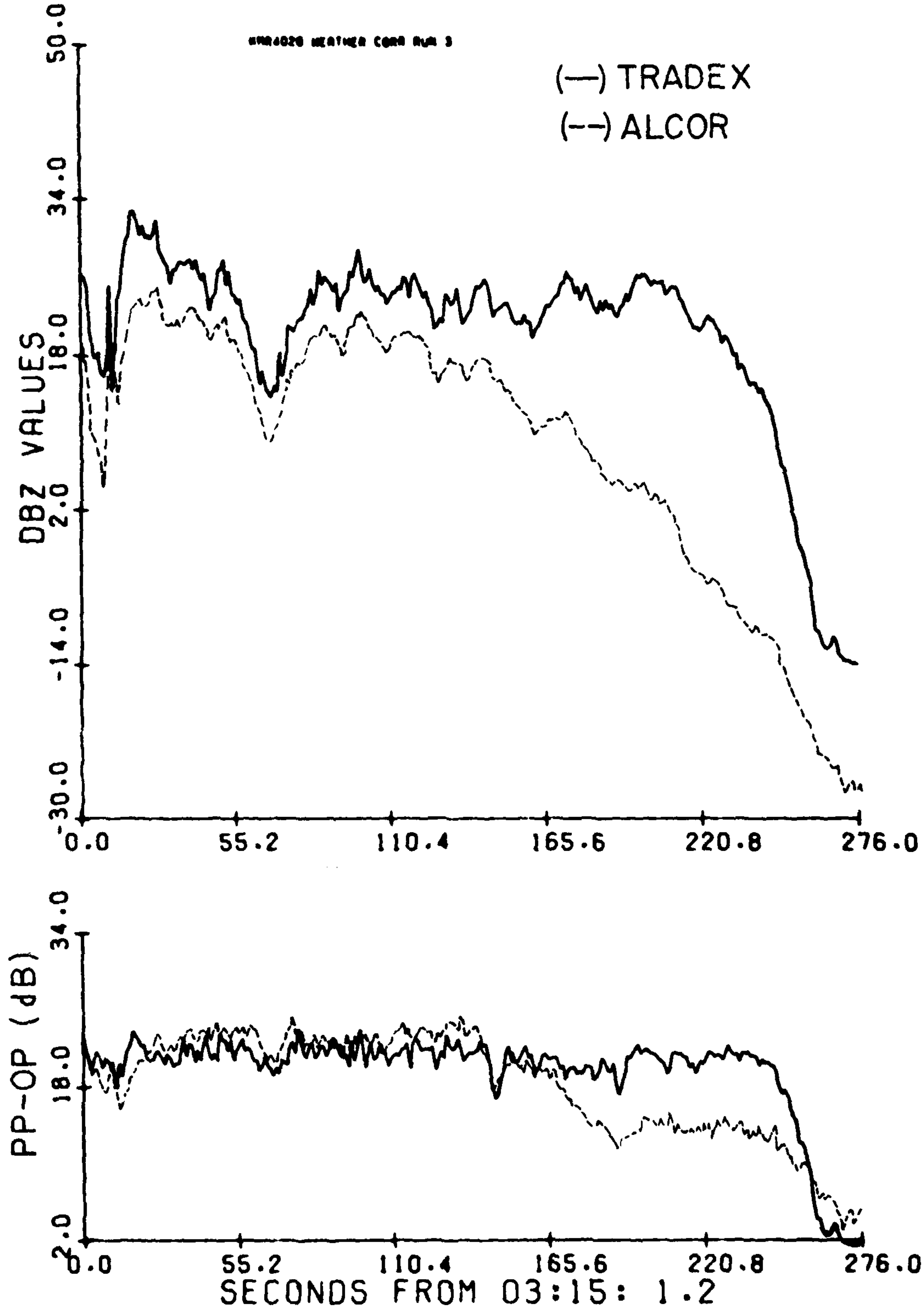


Figure 4 Radar comparisons for Run 3

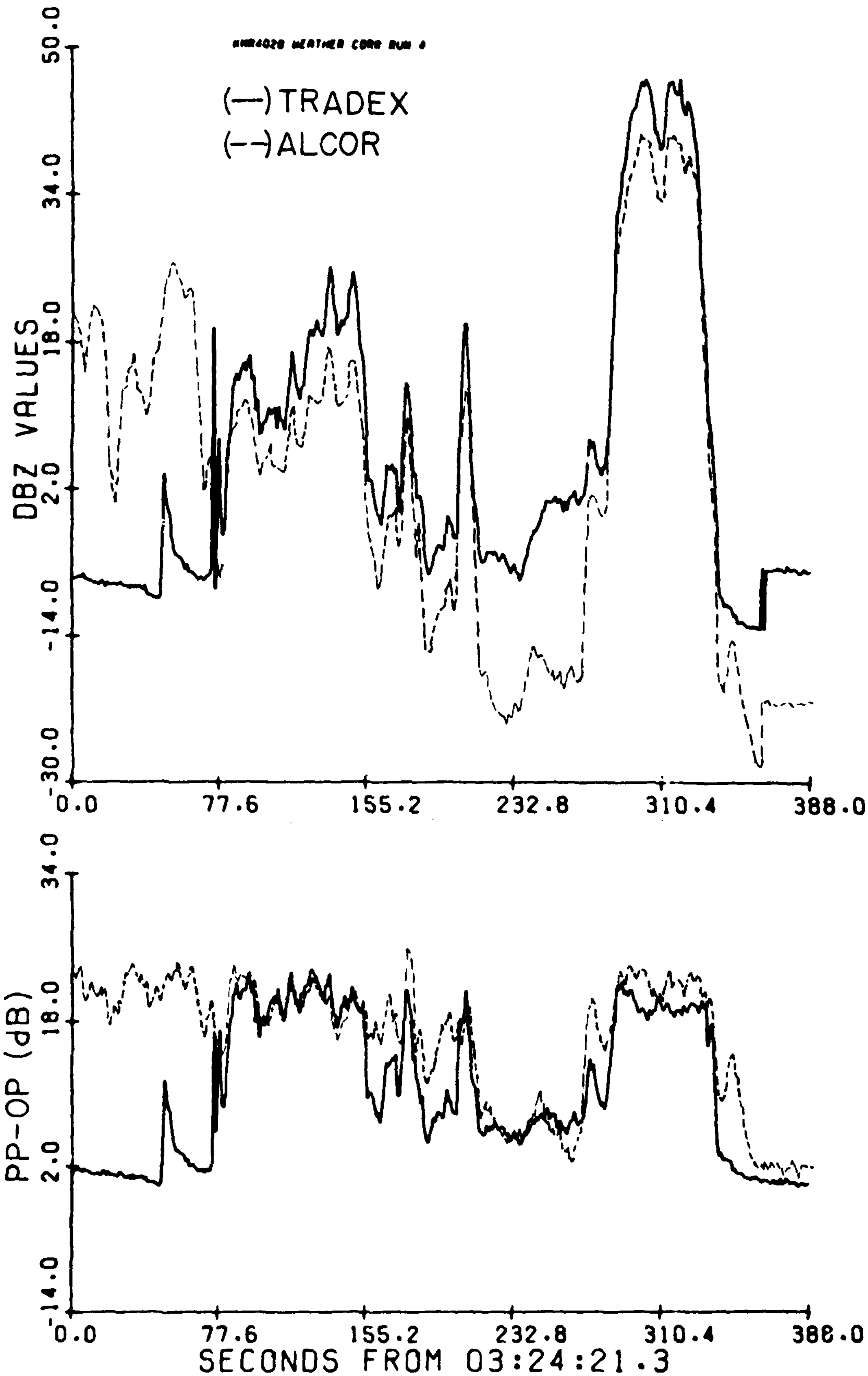


Figure 5 Radar comparisons for Run 4

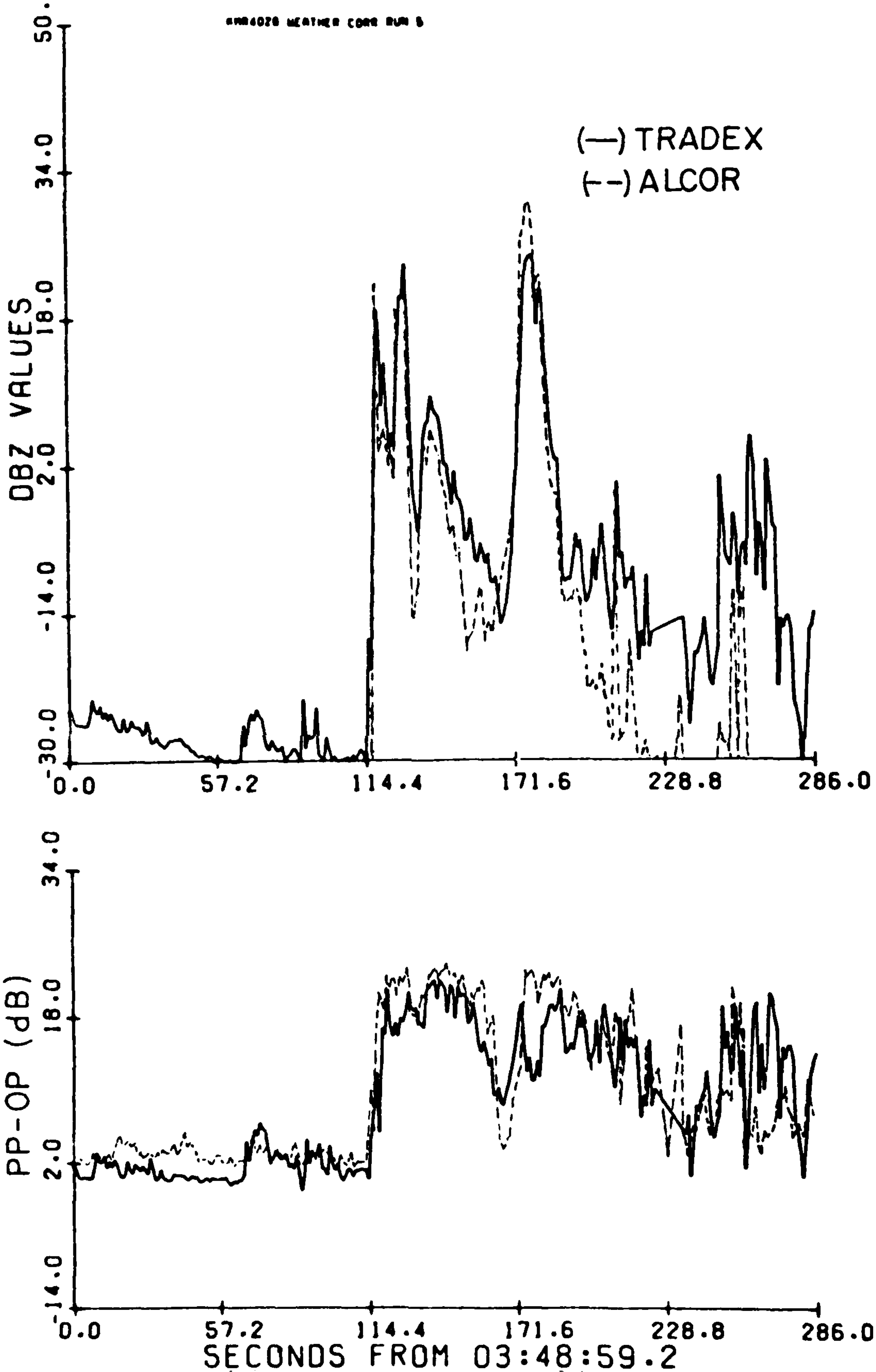


Figure 6 Radar comparisons for Run 5

TABLE 1

MINIMUM EDITING RULES FOR SELECTING
USABLE RADAR BACKSCATTER DATA FROM RAIN

Range of dBZ	Minimum Rule*	Ideal (Theory)
If dBZ < 0,	then PP-OP > 20 dB	off scale
0 ≤ dBZ < 10,	then PP-OP > 19 dB	-
10 ≤ dBZ < 20,	then PP-OP > 18 dB	30
20 ≤ dBZ < 30,	then PP-OP > 17 dB	25
30 ≤ dBZ < 40,	then PP-OP > 15 dB	20
40 ≤ dBZ < 50,	then PP-OP > 13 dB	17
50 ≤ dBZ < 60,	then PP-OP > 12 dB	15
60 ≤ dBZ ,	then PP-OP > 11 dB	14

*Somewhat arbitrary at lower dBZ values due to lack of knowledge of noise statistics influencing the PP/OP ratio.

Some runs were good and some went from good toward a worsening condition (run 3 for example). In no case when radar attenuators were switch-in, thus maintaining the proper dynamic range, did "step function" changes occur in the dBZ values; this suggests that there was never an improper calibration constant in use.

On run 3 when conditions worsened, the region affected was localized. Figure 1 shows darkened regions along the trajectory of the tracked scattering volume which correspond to high regions of backscatter. The beginning and end times of these scatter regions permit a crude mapping of the boundaries of the storm regions outlined on the figure. The region of poor backscatter agreement is also shaded in Figure 1. Upon closer examination of the azimuthal weather scans taken at ALCOR at 0135 and 0334 GMT at low elevation angles (2.3°) a "clutter notch" was observed to exist at precisely the azimuths in question (140° to 155° azimuth). This notch can account for at least 10 dB in the drop of ALCOR dBZ levels when looking at these azimuths at low elevation angles. It should be noted that the radar elevation angles being designated to the KREMS radars ranges from 2.0 to 2.5 degrees in the shaded region of Figure 1. Figure 7 is a tracing of the azimuthal scan taken at ALCOR at the conclusion of run no. 4 (2.3° elevation). A "clutter notch" is shown at the indicated azimuths. Correspondingly, the rain scatter region of interest (R = 80 to 110 km) shows a reduced amplitude (speckled pattern) versus the more solid region (cross hatched) observed at azimuths greater than 155°. It is this localized "attenuation" effect which is the prime cause of the lower ALCOR scatter observed in Figures 2, 3 and 4. The cause of this is probably attributable to local palm tree obscuration (screening) at these particular azimuths at low elevations affecting only the ALCOR radar, physically set into and behind the trees.

The local screening effect at ALCOR does not adequately explain the poor PP/OP ratios at both TRADEX and ALCOR during these times. Another feature identified in the 0334 GMT scan at ALCOR (Figure 7) was

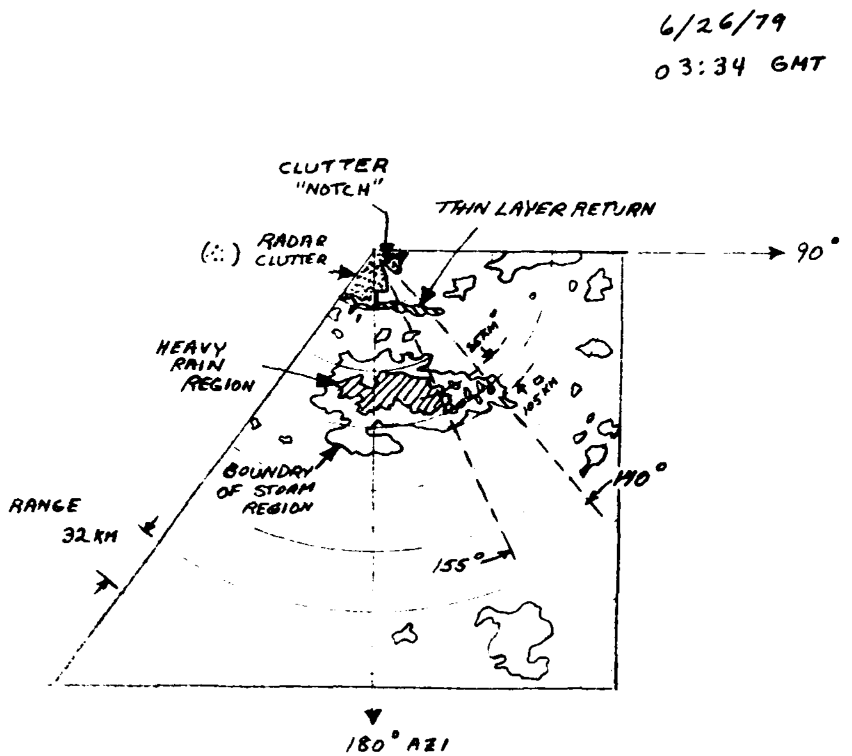


Figure 7 ALCOR azimuthal weather scan - 2.3° elevation

that classed as a "thin layer return" over similar azimuthal regions. On the corresponding vertical scan taken at 0339 (not shown, 179° azimuth) this return may be identified as a thin (in vertical extent) layer type of return perhaps related to a refractive duct being present producing an apparent 2 km high return mid-way between the radars and the scattering volume of interest. It is not known whether this is an actual backscattered return at this height or perhaps more likely a "ghost" return of sea clutter produced at the proper elevation angle by rays being "refracted-in" by a ducting layer. Indeed, evidence was available from an earlier radiosonde profile that a strong ducting condition existed in the refractivity versus height profile (Figure 8). If the ducting layer prevailed at the indicated height over the Atoll it would have refracted rays at ranges of only 15 to 25 km producing the apparent sea-scatter return at the 30 to 50 km. In any case, the thin layer return of Figure 7 may be an indicator of refractive conditions which could be responsible for the polarization ratio degradation on TRADEX and ALCOR by producing a tropospheric multipath type of scattering return from the rain volume of interest. The latter explanation, though somewhat tenuous due to inadequate supporting data, does point to the hazards of low elevation measurements and of collecting data during periods of potential duct situations.

An analysis of the ALCOR extended range gate data (about the tracking cell range) was performed in search of possible time sidelobe interference produced by a hard return from the aircraft itself. All of the poor dBZ agreement regions were processed from the ALCOR narrow band waveform data. The result from this study was that no evidence of a hard body (discrete return) target was identified as affecting the ALCOR radar data.

4. Conclusions

1. It appears that the ALCOR data taken on runs 1, 2 and parts of 3 are unusually low in amplitude due to a local screening problem identified in the radar sea clutter return.

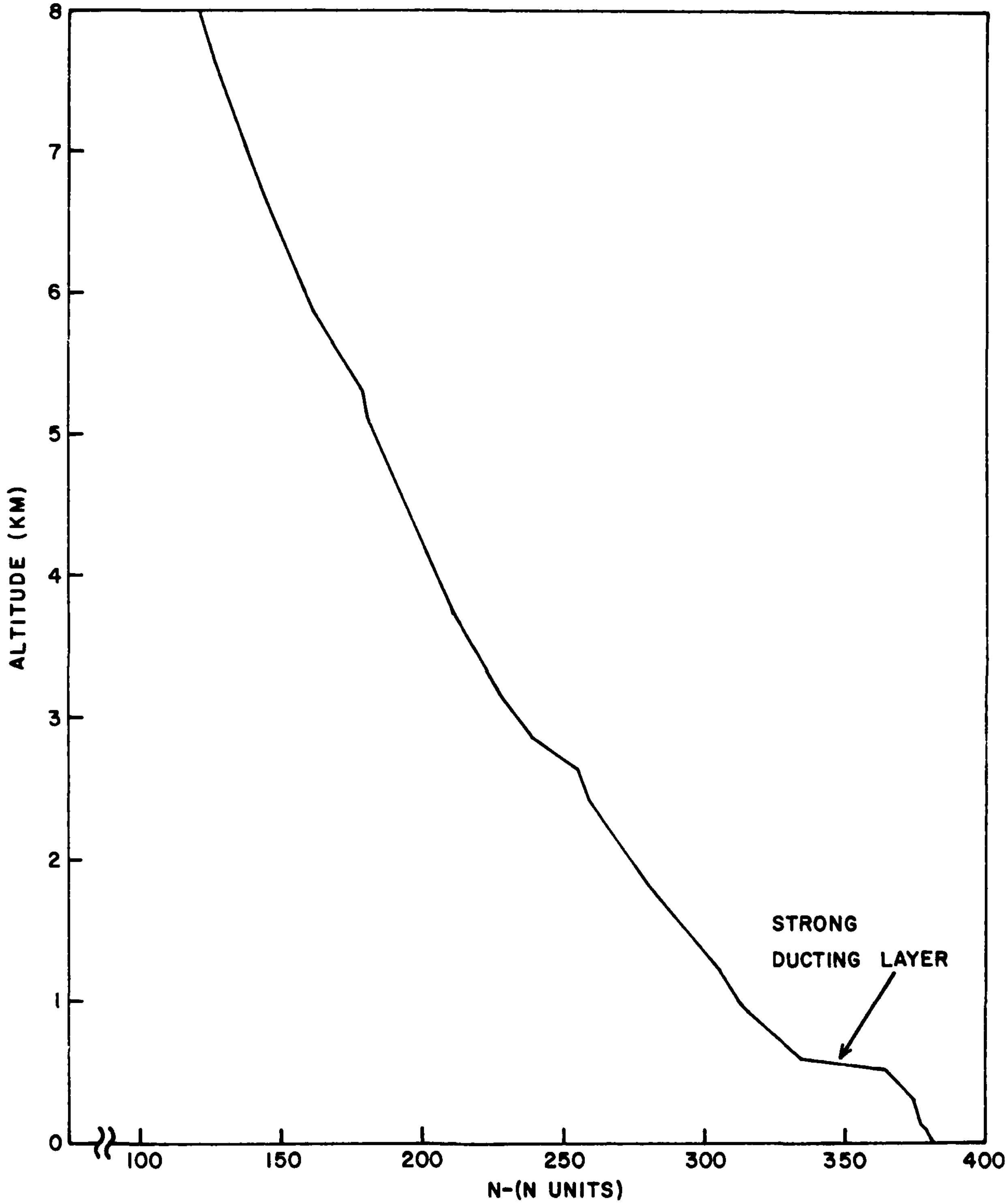


Figure 8 Refractivity profile at Kwajalein for 2300 GMT on 25 June 1979

2. The lower PP/OP ratio on these runs appears to be due to a totally separate propagation problem affecting both TRADEX and ALCOR at the low elevation angles $\Theta < 2.5°$ and long ranges $R > 80$ km. This may be attributable to a refractive layer effect over the Atoll.

3. The minimum editing rules developed (Table 1) should permit a technique for selecting useful rain backscatter data for weather correlation analysis.

5. Recommendations for Next Series

1. Low elevation angle ALCOR data should be avoided due to local terrain features at certain azimuths from Roi-Namur.

2. Low altitude, long slant range runs should be avoided when possible with KREMS or the tracking radar unless radiosonde measurements show no evidence of refractive layers present at the time of the weather runs.

3. Sphere calibrations are advisable in the immediate time frame of the tests.

4. In general, if only one radar were available, TRADEX would be preferred over ALCOR.

APPENDIX C

CIRRUS CLOUD PARTICLE DETECTABILITY
USING THE KWAJALEIN RADARS

David W. Blood

APPENDIX C

CIRRUS CLOUD PARTICLE DETECTABILITY USING THE KWAJALEIN RADARS

1. Introduction

Recent investigations of clear air turbulence backscatter with the Kwajalein (KREMS) radars has led to a reassessment of cirrus cloud (ice particle) detectability by making use of coherent signal processing techniques. The ability to make measurements of low particle densities of tenuous clouds by radar is of interest to the question of re-entry vehicle (RV) surface erosion and the triggering of the transition between laminar and turbulent flow which may occur at altitudes of about 10 km for otherwise smooth, slender re-entry bodies. The particle sizes of concern are ice crystals of diameter greater than 70 microns and at densities of only a few particles per cubic meter. At these levels of occurrence, sensitive radars may provide the practical means to map remotely the atmospheric environment along the re-entry corridor.

For clear air turbulence (CAT) backscatter measurements, the radial component of the wind may be sensed due to the Doppler shift of the CAT scattered energy[1]. The same mechanism may be anticipated for cloud particles in that the spectral returns for radar viewing angles off-vertical will be Doppler shifted by the prevailing winds at altitude. If viewing azimuths are other than tangential to the wind vector (i.e. toward or away from the wind direction) the received signals are shifted spectrally away from the stronger sea and land clutter signals obtained near zero Hertz (0 m/s velocity). The coherent processing capability therefore affords the possibility of several tens of dB improvement over the non-coherent detectable level of the radars previously considered[2]. The required geometry is achieved at the Kwajalein Atoll with KREMS radars viewing the RV's toward the prevailing winds for typical situations. Figure 1 shows an example of CAT returns sensed using the TRADEX (L-band) radar at a range corresponding to the height of 5.7 km (Ref. 3). A similar return to the "turbulence" return may be expected from ice particles at higher altitudes and with radar velocity components corresponding to the winds at cloud heights.

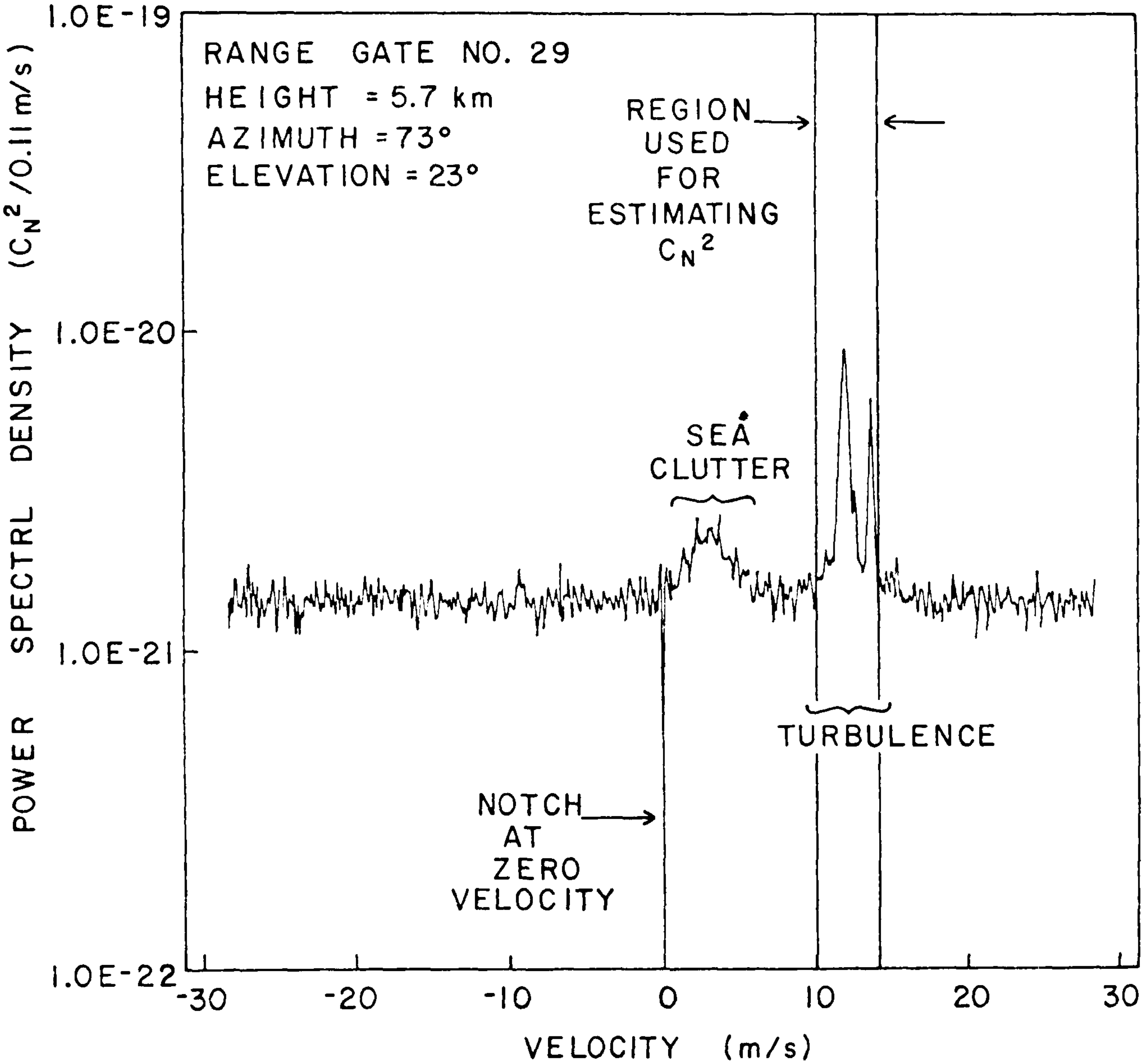


Figure 1 Sample velocity spectrum obtained from TRADEX

2. Weak Cirrus/Ice Detectability

With the ALTAIR (VHF/UHF) and TRADEX (L & S band) radars several high-energy waveforms exist which have Doppler processing potential together with adequate range resolution for consideration in cirrus cloud particle detection. The unambiguous velocity window (for the radar wavelengths) ranges from 40 to 60 m/s along the radar line-of-sight. This window has proven adequate for most wind-measurement observations. The ALCOR (C band) radar, although having a smaller wavelength appropriate for ice crystal detection, has limitations in energy and unambiguous velocity ($\sim$ 6 m/s) which do not provide an overwhelming advantage over the use of the lower frequencies. Table 1 lists the radar parameters and comparative detectabilities of the more appropriate waveforms. From the list, the TRADEX L-chirp, S-chirp or ALTAIR UCWL waveforms, for example, should provide alternatives to the use of C-band and make the separation in the spectral domain more feasible.

The minimum detectable structure constant Cn^2 is computed in Table 1 at a 5 db S/N level and for a radar slant range of 42 km. This range corresponds to a height of about 10 km but within the re-entry corridor for low angle target trajectories impacting short of the lagoon from Vandenberg AFB. The length of observational time used throughout is 80 seconds, the duration found adequate for CAT backscatter/wind measurements. Equivalently, the reflectivity factor Z and the structure constant Cn^2 are related by:

$$Z = \frac{0.3786\ (Cn^2 \times 10^{18})\ \lambda^{11/3}}{\pi^5\ |k'|^2} \quad (mm^6/m^3) \tag{1}$$

where λ = radar wavelength (m),

Cn^2 = structure constant ($m^{-2/3}$), and

$|k'|^2$ = 0.209 for ice particles.

It is evident that 5 dB S/N levels can be obtained for dBZ values as low as -50 dBZ with coherent processing and at the 42 km slant range. It is necessary for the radar beam to dwell for an 80-second observational period at the desired azimuth and elevation angle to obtain these sensitivities. Since it is only the detection of particles, not the Doppler

TABLE 1

CIRRUS CLOUD/ICE PARTICLE DETECTABILITY WITH KWAJALEIN KREMS RADARS AT 42 KM† RANGE

RADAR/ WAVEFORM	WAVE-LENGTH λ	RANGE RESOLU-TION	BEAM-WIDTH	MIN. OBS. RANGE	SENSITIVITY (single pulse)		MAXIMUM PRF	COHERENT PROCESS-ING IMPROVE-MENT	MINIMUM DETECT-ABLE Cn^2 ††	MIN. DET REFLEC-TIVITY (ICE)	DETECTABLE NO. OF ICE PARTICLES		UNAMBIGUOUS VELOCITY
					$1m^2$ S/N @ 1000 km	MIN. Cn^2 @ 42 km					70μm DIAM	80μm DIAM	
	(m)	(m)	(deg)	(km)	(dB)	(dB Cn^2)	(pps)	(dB)	(dB Cn^2)	(dBZ)	(N/m^3)	(N/m^3)	(m/s)
ALTAIR													
VCSL	1.93	4500	2.8	5.7	23	-174	372	33	-202	-34	3480	2650	±19.3
U-T2L	0.722	537	1.06	7.5	32	-165	120	28	-188	-35	2390	1820	±21.7
UCWL	0.722	2400	1.06	3.0	28	-169	372	33	-197	-44	300	230*	±21.7
UXL	0.722	6000	1.06	7.5	31	-175	120	28	-198	-45	240	180*	±21.7
TRADEX													
L-CHIRP	0.227	194	0.65	9.4	26	-154	1500	37	-186	-52	55	42**	±28.4
L-20-HIGH	0.227	11	0.65	9.4	26	-141	1500	37	-173	-39	1090	830	±28.4
S-NB-CHIRP	0.102	12	0.29	1.7	27	-136	1500	35	-166	-45	285	220*	±19.0
ALCOR													
C-NB	0.0529	58	0.30	1.9	23	-139	200	25	-159	-48	130	100	±2.6

NOTES:

†† corresponds to observations at a height of 10 km in re-entry corridor for a low ∠ trajectory to impact 72.

† 5 dB S/N @ 42 km range with both non-coherent and coherent processing over 80 sec. obs. time.

* alternative radars/waveforms providing comparable detectability with ALCOR (C-band).

** could detect 3 particles/m^3 @ 10 km (near overhead) with 5 dB S/N or 15/m^3 @ 42 km range with unity S/N.

velocity that is of interest, it is not necessary for the radar to scan in azimuth as was the requirement for wind measurements.

The ice particle densities are also listed in Table 1 for ice particles greater than 70 and 80 microns in diameter as derived from Burke et al., 1978. Possible waveforms for detecting tenuous particles (lower densities of a few per meter^3) would be the ALTAIR (UHF) UCWL waveform or TRADEX L or S band chirp waveforms. The ALTAIR UXL and VCWL waveforms, though high energy, may not offer adequate height resolution (1.45 km and 1.09 km respectively at the radar range resolutions of 6000 meters at UXL and 4500 meters at VCWL) for the measurements at 42 km slant range.

With the TRADEX L-chirp waveform, the lowest particle densities are obtained. Forty-two particles per cubic meter should be detectable for particle diameters larger than 80 microns. Correspondingly, the same waveform could detect only three particles/m^3 at near overhead geometries with a 5 dB S/N or 15 particles/m^3 at 42 km range but with unity S/N ratio. A longer integration time could further improve upon these sensitivities. The corresponding altitude resolution would be near 200 meters at high elevation angles or 50 meters at 42 km range.

3. Operational Configuration

It will be necessary to distinguish between clear air turbulence returns (in the absence of ice) and scatter from cirrus cloud ice particles alone. This may be accomplished by the use of two frequencies illuminating the same volume. If CAT provides the scatter mechanism, the two radars should sense the same structure parameter, Cn^2 at the same altitude. Figure 2 shows altitudes where cirrus particle backscatter could not be easily distinguished on a single radar frequency from CAT returns (shown from Ref. 3) because of similar levels of backscattered returns. Given only cirrus particles at a particular altitude, a different equivalent Cn^2 level would be sensed with two frequencies and the more sensitive radar would dominate in detecting these particles. It should be possible therefore to eliminate CAT as the scatter mechanism in question on a Cn^2 display containing two radar frequency outputs versus altitude. A three-frequency (two radar) technique would provide even a more positive identification of scatter type.

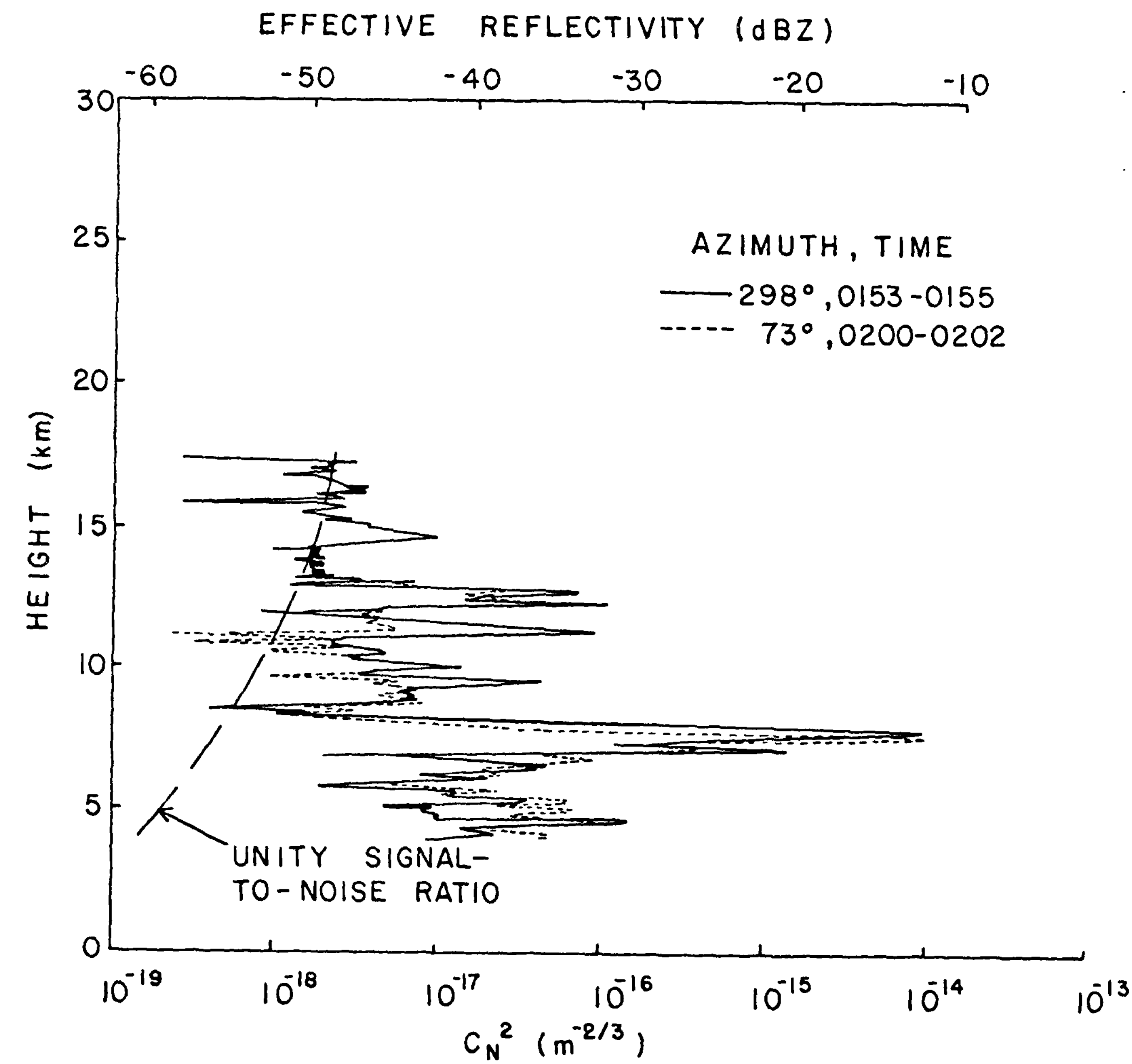


Figure 2 Structure parameter Cn^2 profiles obtained from TRADEX on 28 December 1977

4. Conclusions

The sensitivity calculations of Table 1 indicate the potential of KREMS radars in detecting cirrus cloud ice particles at low levels of density within the re-entry corridor. Alternatives for even more sensitivity are to search at higher elevation angles or integrate for periods longer than 80 seconds. Coherent (Doppler) processing of the returns to gain this sensitivity is most promising by using the TRADEX and ALTAIR waveforms as opposed to the ALCOR C-NB waveform. A two (or three) frequency method should offer a means of positive identification of the particle returns from those produced by turbulence. Using the multiple frequency observation technique, 80 um particles with densities as low as 42 m^{-3} would be detectable (TRADEX L-chirp) at a range of 42 km in the presence of turbulence of the intensities observed to date at Kwajalein.

5. References

1. Crane, R.K., 1980: "Radar Measurements of Wind at Kwajalein", Radio Science, Vol. 15, No. 2, 383-394, March-April.

2. Burke, H.K., A.J. Bussey and K.R. Hardy, 1978: "Thin Cirrus Cloud Over the Tropical Pacific", AFGL Scientific Report No. 3, AFGL-TR-78-0259, Environmental Research & Technology, Inc., P-1996-673F, October.

3. Crane, R.K., J.E. Salah and G. Weiffenbach, 1980: "Wind Velocity Measurements at Kwajalein Using the KREMS Radars", MIT Lincoln Laboratory, Project Report RMP-181 (in publication).

APPENDIX D

THE AFGL-1 DECISION TREE FOR LIQUID WATER CONTENT ASSIGNMENT

Shu-Lin Tung

APPENDIX D

THE AFGL-1 DECISION TREE FOR
LIQUID WATER CONTENT ASSIGNMENT

1. Introduction

The AFGL-1 model is a technique for converting standard meteorological observations to liquid water content profiles. It is designed for computer applications and has been applied to data for the USSR. A decision tree is used to assign the liquid water content of each atmospheric layer. The summaries of the analysis and procedure are presented in the following sections.

2. Analysis

The analysis consists of converting the observational data for each time and place into a liquid water content (LWC) profile. The key factors to assign the liquid water content are the temperature profile, the weather condition at the surface, the present convective activity and the precipitation condition at each level. In order to get the LWC profile, four temperature regions ($T \leq -30°C$, $-30°C < T \leq 15°C$, $-15°C < T \leq 0°C$, $T > 0°C$) are used to separate the precipitation types, which are combined with the surface weather conditions (moderate, heavy or light precipitation) and the cloud convective activity to vary the liquid water content values. In the first region, ice water contents vary from 0.1 to 0.2 g/m^3 depending on the weather and convection. In the second region, snow water contents vary from 0.4 to 1.2 g/m^3 and ice water contents are assigned from 0.1 to 0.15 g/m^3 for the layers without weather and convection. In the third region, snow water contents vary from 0 to 1.2 g/m^3. In the fourth region, rain water contents vary from 0 to 0.5 g/m^3. Flag 1 indicates precipitation or convection without saturation in the sounding; the analysis then has to readjust the relative humidity or dew point depression. Flag 2 indicates moderate or heavy precipitation without saturation at specific layers. Any unsaturated layers between saturated layers are also flagged for analysis (see flow diagram).

3. Procedure

The procedure to assign the LWC profile is as follows:

(1) check and correct observation data;

(2) match surface and radiosonde observation for time, date and station;

(3) categorize surface weather;

a. precipitation - based on current weather (ww) in surface observations

1. moderate or heavy

ww (current weather code)
62, 63, 65, 65, 67, 69, 72, 73, 74, 75, 81, 82, 84, 86, 88, 90, 92, 94, 97, 99

2. light

ww = 16, 60, 61, 66, 68, 70, 71, 76, 77, 78, 79, 80, 83, 85, 87, 89, 91, 93, 95, 96, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59

3. none

ww = other code numbers

b. convective activity

Cl (low cloud type) = 2, 3, 9

ww = 17, 18, 19, 25, 26, 27, 29, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99

(4) starting at the top level, assign a liquid water content according to the flow diagram in Figure 1.

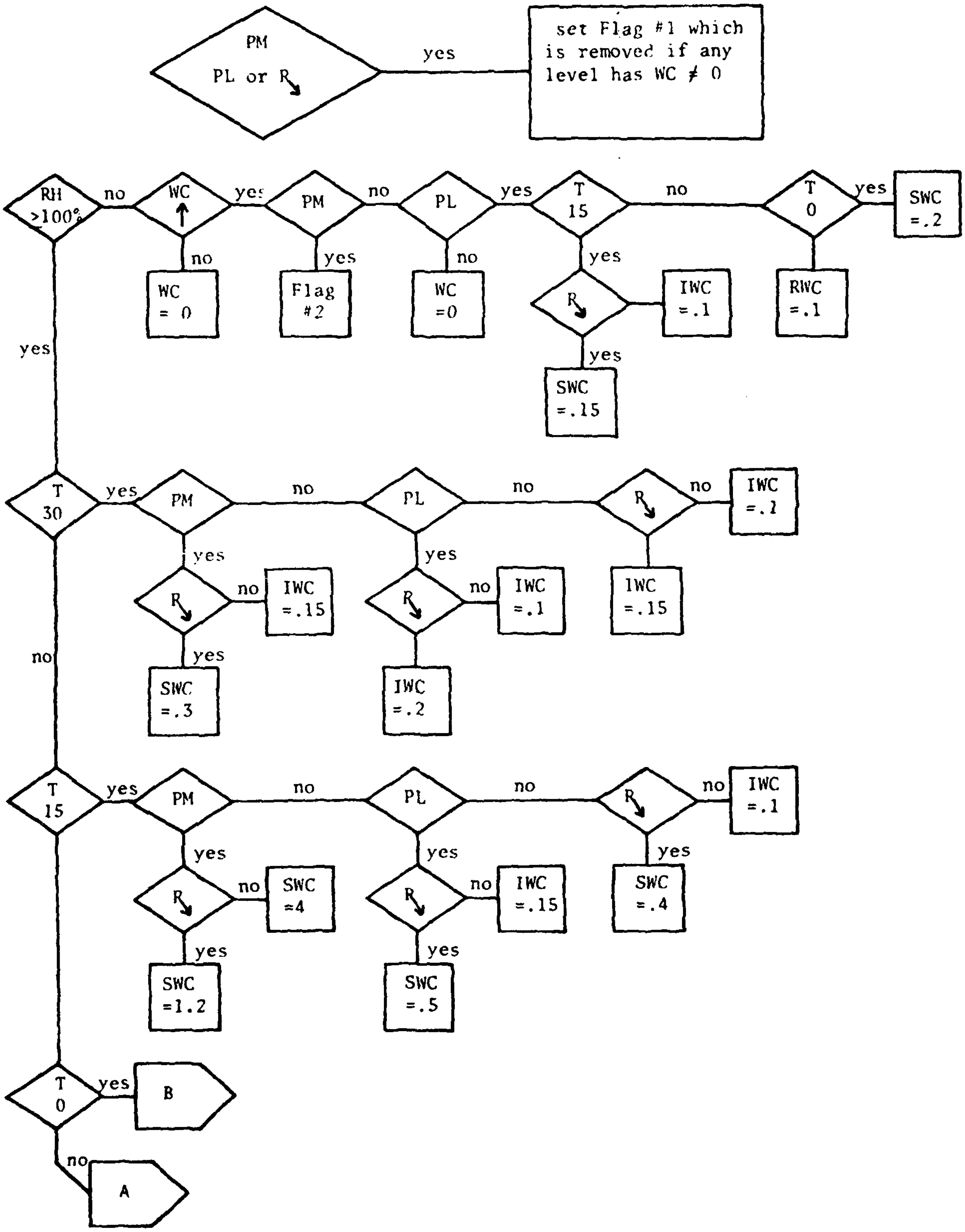
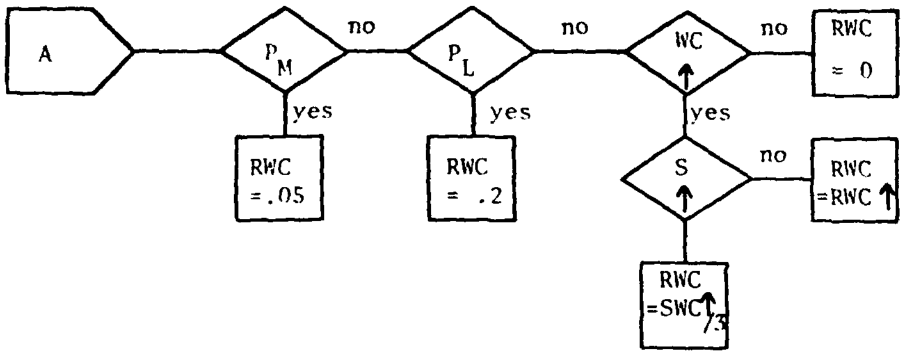
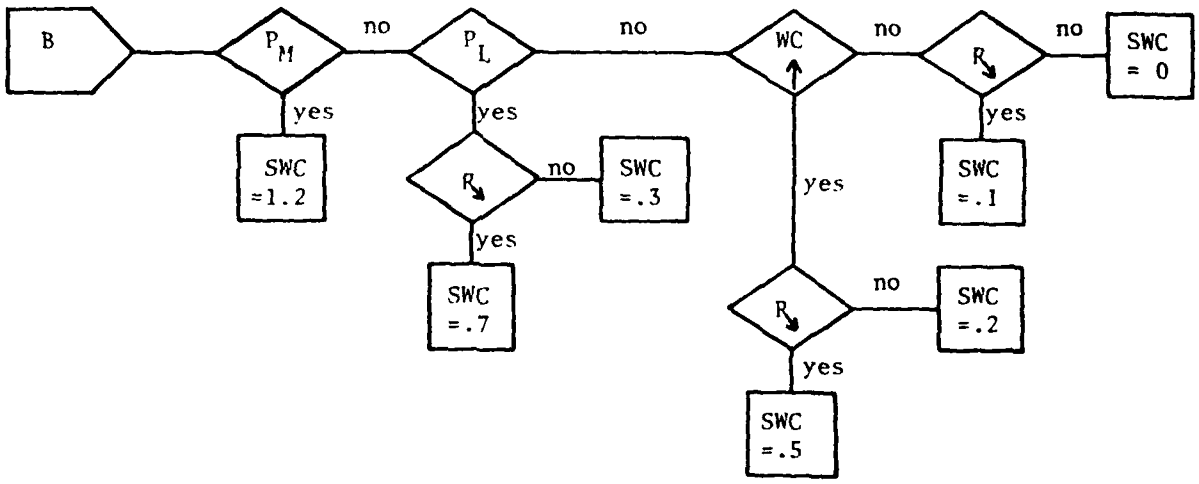
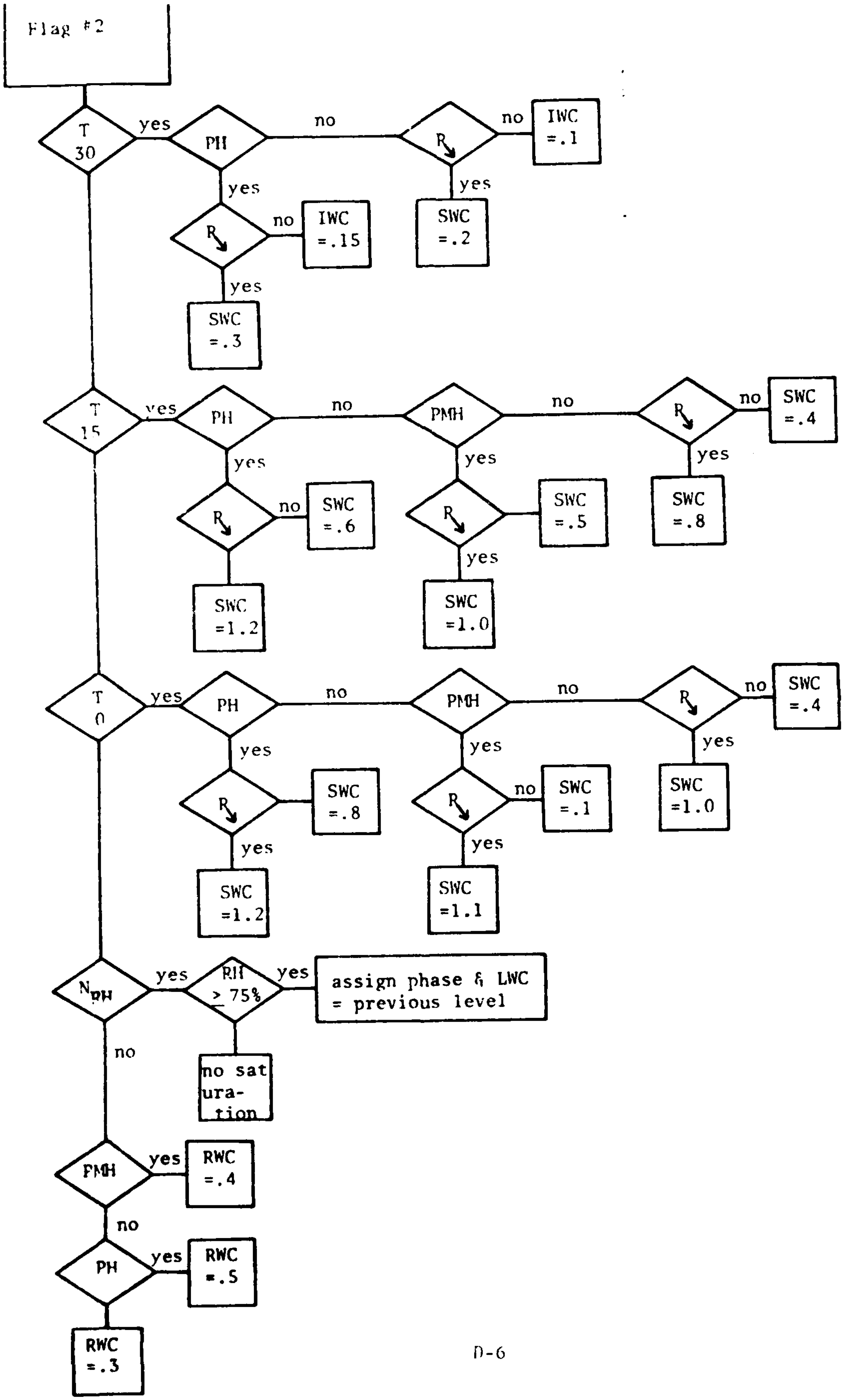


Figure 1 Flow diagram for assigning the liquid water content to cloud and precipitation layers. The key to the symbols in the diagram are provided in the last page of the appendix.





- the phase and water content are assigned for each level beginning from the highest level
- when the phase and/or water content change, the height at which the change occurs is determined by extrapolation on either relative humidity or temperature, whichever caused the change



Flag #2
T 30
yes
PH
no
R
no
IWC =.1
yes
SWC =.2
yes
R
no
IWC =.15
yes
SWC =.3
T 15
yes
PH
no
PMH
no
R
no
SWC =.4
yes
SWC =.8
yes
R
SWC =.5
yes
SWC =1.0
yes
R
no
SWC =.6
SWC =1.2
T 0
yes
PH
no
PMH
no
R
no
SWC =.4
yes
SWC =1.0
yes
R
no
SWC =.1
yes
SWC =1.1
yes
R
SWC =.8
yes
SWC =1.2
N PH
yes
RH ≥ 75%
yes
assign phase & LWC = previous level
no saturation
no
PMH
yes
RWC =.4
no
PH
yes
RWC =.5
RWC =.3

KEY TO THE FLOW DIAGRAM

WC ↑ = PRECIPITATION IN LEVEL IMMEDIATELY ABOVE = $\dot{WC} \neq 0$

T_{30} = TEMPERATURE $\leq -30°C$

T_{15} = $-30°C <$ TEMP $\leq -15°C$

T_0 = $-15°C <$ TEMP $\leq 0°C$

P_M = MODERATE OR HEAVY PRECIPUTATION AT GROUND

P_L = LIGHT PRECIPITATION AT GROUND

R↘ = CONVECTIVE ACTIVITY PRESENT

S ↑ = SNOW IN LEVEL IMMEDIATELY ABOVE

N_{RH} = ANY LEVEL RH $\geq$ 100%

PH = PRESENT WEATHER CODE = 64, 65, 74, 75, 82, 97

PMH = PRESENT WEATHER CODE = 67, 81, 84, 86, 88, 90, 92, 94

SWC = a = PRECIPITATION IS SNOW, WC = a

IWC = a = PRECIPITATION IS ICE, WC = a

RWC = a = PRECIPITATION IS RAIN, WC = a

DATE
ILMED

-8